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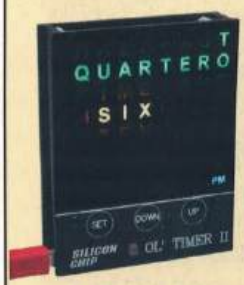

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Editorial Viewpoint

The paperless office . . . and working from home

When I took over the publication of SILICON CHIP two years ago, I didn't want to make many changes to the magazine or the way it was run. But one thing that I did straight away was to change from a paper-based filing system to an electronic system.

One reason for this is that it was quite a bit of work shredding all the filed paper that we no longer needed to keep. And during the five to seven years or so that we had to keep them, the files took up quite a bit of space (six or so tall filing cabinets worth). By comparison, electronic records take up no real space and deleting them takes no time at all.

Storing the files in paper form also made them harder to search; since I didn't do the filing, I couldn't find documents easily. The Australian Tax Office decided some time ago that virtually all tax-related records can be kept in electronic form. Since my personal tax affairs became much simpler after switching to electronic storage, I decided to do the same with SILICON CHIP.

That decision paid off quite nicely when we decided to work from home starting in late March, when the Australian government advised that workers should stay home if possible, to curb the spread of COVID-19. Because we were already handling financial documents like invoices as digital files, and almost all our bills were coming in via e-mail, running the business remotely was not too difficult.

Another great benefit of communicating via e-mail and archiving all e-mails became apparent recently. My accountants asked me for details of various bank transactions that occurred during the business takeover. I couldn't remember the reason for most of them. But searching back through e-mail correspondence at the time allowed me to quickly figure out the purposes of all those transactions.

The only things we print these days are article proofs for checking and letters to send out to subscribers who either don't have e-mail, haven't told us their e-mail address or who ignore e-mails that their subscription is about to expire. And now that we're mostly working from home, we rarely even print article proofs. So our office printers are seeing little action.

It is somewhat easier to mark up printed proofs, but I do proofreading on-screen quite regularly. And there are several applications which allow documents (in our case magazine articles) to be shared amongst staff and marked up "on screen" if required.

So we are using much less paper and ink than we used to (except perhaps for the magazine itself!).

I'm also happy to report that moving to a distributed workforce was not too difficult. As luck would have it, since I have young children and I have to take care of them sometimes, I had already set up our computer systems so that I could work from home.

All I had to do was use the same systems to give other employees access to our office resources remotely, so they could use their home computers on our network and/or they could take their computers home and work remotely in an almost seamless fashion.

Not surprisingly, the biggest challenge when everyone is working from different locations is communication. But we all have e-mail and can hold discussions and exchange files quite easily. We also have the phone for those times that e-mail is just too awkward.

This has all helped us keep the magazine going as-normal even through this current crisis.

I'm glad to report that SILICON CHIP will remain as strong as ever as life (hopefully) slowly returns to normal.

Nicholas Vinen

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Feedback on PDFs and various projects

It's fantastic that you have finally converted all SILICON CHIP issues to PDF format – and they are searchable! Thanks and well done! I have downloaded a few issues while waiting for my USB drive to arrive.

It's really a joy to have PDF versions on top of the paper issue (that I read most over the digital version) thanks to the hyperlinks and the possibility to browse issues quickly with your index.

Recently, I had more time to complete a couple of projects. I built a second High Visibility 6-Digit LED GPS Clock (December 2015 & January 2016; siliconchip.com.au/Series/294) as I just love it; it's so cool with its large display, its GPS accuracy and remote control!

I also completed the GPS-synched Frequency Reference (October-November 2018; siliconchip.com.au/Series/326). It's a great piece of equipment. I noticed that getting a GPS fix indoor is very difficult even by the window, unlike with the 6-Digits Clock. The latter gets a fix in less than a minute from a cold start, even away from the window or behind a wall.

So I tested a bunch of VK2828U7G5LF receivers I have in my collection: I connected them up to an Arduino to decode the NMEA stream and make sure they all worked properly. Then I swapped different receivers, but the results are the same. If the Frequency Reference is outside in plain sight, however, I get a fix quickly.

Hooking a scope shows a ~15% overshoot at the output; it that expected? The closest accuracy I could get was around 3-4ppm with the 10MHz output.

I also converted the Touchscreen Super Clock (July 2016; siliconchip.com.au/Article/10004) into the new Indoor Air Quality Monitor (February 2020; siliconchip.com.au/Article/12337). It is very useful when using flux remover, for instance.

Finally, I completed my version of your Flip-dot Message Display (April 2019; siliconchip.com.au/Article/11520).

Though I built 10 "digits", I ended up daisy-chaining four of them together with an ESP8266. It connects to my WiFi network, then to an NTP server, retrieves the time as UTC, converts and formats it before feeding the Arduino (I replaced it with a Nano version to fit it in between the PCBs). It works very well; I will most likely build an acrylic case to reduce the noise.

Olivier Aubertin,
Singapore.

Comment: we wonder whether the GPS module orientation is affecting the sensitivity of the GPS module in your frequency reference, or perhaps EMI from the device itself is interfering with the GPS signal. For projects like this, a module which accepts an external antenna could be a worthwhile upgrade.

The PLL chip used in that project does seem to produce some overshoot on its outputs. We would have expected better than 3-4ppm accuracy. It's possible that the disciplining algorithm is not operating in an ideal manner.

Note that a typical spectrum analyser has an oscillator drift of around 1ppm/°C. So unless you are using a very precise external reference or have a very high-end unit, a change in its internal temperature of just a few degrees could explain your measurements.

PDF downloads appreciated

Living in Germany, and with all the recent delays in mail delivery, I appreciate your efforts in giving me access to a soft copy of SILICON CHIP. It appears that my

deliveries will be delayed by anything from 4-6 weeks for the foreseeable future.

It is the first time that I have seriously read a magazine as a PDF softcopy and am very surprised that it has many advantages.

Firstly, all the links can be quickly and easily opened to check them out. Secondly, the images can be enlarged to see lots of details. Finally, searching for keywords or whatever is very easy. Of course, these points also apply to the SILICON CHIP PDF archives you are now offering (siliconchip.com.au/Shop/digital_pdfs).

I really look forward to reading the magazine each month.

Christopher Ross,
Tuebingen, Germany.

Violet McKenzie and the origin of Wireless Weekly

I just listened to a program on ABC Radio National about Violet McKenzie who in the 1920s founded Wireless Weekly, which of course is the ultimate predecessor of SILICON CHIP. You can listen to that episode at siliconchip.com.au/link/ab2t

She also corresponded with Einstein, ran a radio station, trained women as Morse code operators for WW2, and wrote a cookbook, having found that there were no cookbooks that explained how to cook using an electric stove.

The program included commentary by David Dufty who has just released a book on Violet called Radio Girl (published by Allen & Unwin, ISBN: 9781760876654).

Andrew Partridge,
Blacktown, NSW.

Sourcing replacement belts

In Mailbag, May 2020, Randal Grant of Queensland asked about replacement belts for a recorder; I suggest he contacts:

Richard Michell,
134A Ayr Street,
Doncaster, Vic, 3108
Ph. (03) 9850 4144

He has an excellent collection of belts for sale.

I viewed with interest your reflow soldering oven project; unfortunately, I had invested in a hot air rework station the week before, so it was just too late. I was struck though, by the Catch-22 situation. The PCB uses SMD components, so to build it, you need a reflow oven!

The thought also struck me that this system could well have been made using an Arduino Uno with a specialised shield, without the need for SMD components.

David Tuck,
Yallourn North, Vic.

Response: the irony was not lost on the author, Phil Prosser, who made a comment in the constructions section of that article about how useful it would be to have a reflow oven. You are right that it would be possible to build a simpler controller, but the PIC32MZ does provide for a nice graphical user interface. And as Phil had already designed that controller board, and we stock it, reusing it was an attractive option.

As the PIC32MZ chip is very powerful, and it doesn't add a huge amount to the overall cost of most projects (given all the ancillary bits needed like cases, power supplies etc), it makes for a reasonable basis for all sorts of

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designs. Sort of like a 'super Arduino', if you will.

Thoughts on H-Field Transanalyser

Reading the H-Field Transanalyser project part two article in the June 2020 issue (siliconchip.com.au/Series/344) prompted me to write down the following thoughts.

I usually use an oscilloscope as the measuring instrument when doing radio IF alignment; most of the time, I'm working on valve radios. One thing I note on many data sheets (ours seem to be vague compared to German ones) is that there is rarely a signal voltage listed to be fed into a signal grid.

I find a 1kHz audio signal to be handy when working on the audio section of a set. Once I get a set running, I align the IF stages first as the oscilloscope will show distortion etc. If it fires up badly, then the CRO becomes the signal detector. However, an audio tone is handy for all sorts of uncooperative amplifiers.

Since the unit's 1kHz generator is the audio source for the modulator, that means you can feed the audio output of the Transanalyser to the external sync input of the scope. That will give a more stable oscillograph, as any drift will be compensated for.

Marcus Chick,
Wangaratta, Vic.

The best way to test an AM radio

I read with interest the articles on the H-field Transanalyser, by Dr Hugo Holden. As an "all-in-one" generator, it elegantly bundles several "grey boxes" sitting in my test rack into a much more compact and convenient unit.

Dr Holden's coupling method is clearly efficient, but it may be difficult (or impractical) to couple to compact radios, especially ultra-compact "keychain" types.

It is also possible that the signal at the receiver's input terminal (the base of the RF amplifier or converter) will differ from one set to another.

Considering Dr Holden's injection loop as the primary of a transformer, and the tuned winding of a ferrite rod as the secondary, the actual secondary voltage will depend on the number of turns in the tuned secondary, which varies from one design to another.

It is also unclear how Dr Holden's injection method would translate to a set using a wire loop antenna, as is fairly common in portable valve sets.

My testbench uses a radiating loop, placed 600mm from the set. It is calibrated so that 20mV from the signal generator creates an air field of 1mV/m at the antenna of the set.

This method does not rely on the transformer effect. It guarantees a known signal level at the set's antenna, and allows standardisation and comparison of test results.

Readers will discover that, for induction-field antennas such as ferrite rods and wire loops, sensitivity is commonly quoted by designers and manufacturers as millivolts/microvolts per metre of field strength.

My loop is derived from an article in Mingay's Electrical Weekly, October 18, 1963: Pye Caddy Transistor Portable Receiver Service Data Sheet. A full description appears in How Your Transistor Radio Works, published by the Historical Radio Society of Australia. I plan to write up the details of the loop in an upcoming Circuit Notebook entry in SILICON CHIP.

Experience shows that this method also works for wire loop antennas. While the calibration may not be absolute (as it is for ferrite antennas), it is a known standard that allows set-to-set comparisons for relative sensitivity.

Dr Holden also recommends measurement of output at the terminals of the volume control.

This is probably the most convenient method. If a set offers an earphone socket, it is possible to measure the final audio output. Sets lacking the earphone socket demand that one locates the leads to the speaker, and then desolders one of them for connection to an audio wattmeter or dummy load/voltmeter. That can be annoying and difficult.

Against this, the ultimate purpose of a radio receiver is to deliver an intelligible signal at a standard listening level. The "50 milliwatt" standard (initially an IRE requirement for sets with outputs from 100mW to 1W) appears to be commonly-accepted for transistor sets of all kinds, unless their output is under 100mW, where a 5mW output is specified (GE Transistor Manual, 2nd Edition).

Readers will note that I have applied this standard in my articles, except for some very few sets with minuscule outputs.

Adopting an end-to-end calibration of the signal field in milli/microvolts per metre, and an output power of 50mW, allows direct set-to-set comparisons for sensitivity and merit. If a set is tested at only 5mW output, its sensitivity is around one-third that of a 50mW-specified set.

The final part of the puzzle is noise performance. Sony's outstanding TR-712 radio (March 2017; siliconchip.com.au/Article/10588) managed an astounding sensitivity of 9µV/m (0.5µV at the converter base!), but with an unacceptable noise figure of only 4dB – the audio output was hardly more than double that of the noise. In theory, it ought to have been some 20dB.

Dr Holden's Transanalyser readily allows measurement of noise performance, as he has designed the modulation to be switched in or out for this comparison.

Ian Batty,
Rosebud, Vic.

Dr Holden responds: Ian's ferrite rod (like the electrostatically screened loop I mentioned in the article) is another good way to couple into a transistor radio, especially in the case where it is physically difficult to get a loop of wire around the ferrite rod coil. This is the case in some very small compact transistor radios, where the coil is pushed right up against the PCB.

It would also solve the problem of coupling into a frame aerial on a tube radio.

I have always felt it was much better to check the radio's performance at the detector output (volume control top leg) and assess the audio output stages separately for performance with an injected 1kHz tone. This way it is much more apparent, if the performance is poor, in which part of the radio the problem resides.

Testing the response at the earphone socket or speaker, while an IRE standard for testing, is not that helpful for fault-finding.

Hints for anodising aluminium

Thanks very much for Phil Prosser's article on home anodising in the May 2020 issue (siliconchip.com.au/Article/14423). I have been anodising at home using sodium bisulphate for a few years now, and have had a high level of success.

In all cases, the failures that I've had were caused by inadequate cleaning of the part and/or poor surface preparation when I was machining the part.

Any flaw in the surface finish will be twice as apparent once the part is anodised and dyed.

One 'gotcha' with anodising where the anodised parts will be used in electronics projects is that the anodised surface is electrically non-conductive. If you need to have an anodised part electrically connected to some part of the circuit or structure, you need to ensure that the contact area where you want to connect a wire is not anodised.

A small piece of Kapton tape, placed after cleaning and before anodising, to protect a small area works. So does using a Dremel-style tool to wire-brush the anodisation layer away from the Earthing connector point.

Lastly, I have an alternative way to apply colour to an anodised part, for when you need a specific colour (or colour match) that is not available as a dye.

Most of the anodising that I've done has been on parts of cameras and other optical equipment. Any parts within a camera or other optical instrument that are along the optical light path need to be non-reflective matte black. It is very difficult to find a black dye that results in a truly black and very matte anodised surface.

The aluminium oxide layer that is formed by anodising also happens to be an excellent base on which you can apply a layer of paint. A paint layer, applied on to a freshly anodised surface, will be much more durable than simply applying paint on unanodised aluminium.

I use matte black spray paint touch-up cans obtained from a car parts supplier. You may need to use an etch primer under some paints, but most auto shops stock paint that includes an etch primer designed to go directly onto aluminium. Once the paint is completely dry (after 24 hours in my case), I then boil the part as usual to seal it.

Roy Gilby,
Queensland.

Roadies' cable tester

I notice in the June 2020 issue that you describe a Roadies' Test Oscillator (siliconchip.com.au/Article/14466) and there is a request in the Mailbag section for a cable tester that detects intermittent breaks. I would like to bring to your attention the Behringer CT100 cable tester, available for $37 from DJCity Australia.

This unit tests the following connectors: XLR, 1/4" RTS, RCA, 1/8", TT and MIDI. It will test for continuity, display crossovers (ie, 1-2, 2-1 etc), shorts between conductors, intermittent breaks when cables are wiggled, phantom power presence on pins 2 & 3 and incorporates a test tone generator of 1kHz or 440Hz (selectable) with three different levels: +4dBu, -10dBV and -50 Mic.

It is housed in a robust folded metal box (decent gauge) and is powered from a 9V battery which seems to have quite a decent life, probably because such a device is used intermittently. I think that this unit provides exactly what Graham Goeby is looking for and more. I also doubt that you could design a project with these features that could be constructed for the asking price or less.

The only thing lost by SILICON CHIP designing such a unit (lamentably) is the joy of the construction.

Ingo Evers,
Higgins, ACT.

Comment: Jaycar and Altronics also sell comprehensive cable testers with different capabilities, with catalog codes of AA0405 and Q2022 respectively.

QNH is not an altitude

I would like to point out that the terminology used in the display for your Touchscreen Car Altimeter (May 2020; siliconchip.com.au/Article/14431) is wrong.

It reads "feet above QNH", but QNH is a pressure value calculated using a specific method, based on the local atmospheric pressure, local altitude and assumed temperature profile. It is not an altitude. It would be more accurate if the display read "xxx feet ref. to QNH" (or metres, as appropriate).

Lawrence,
via telephone.

Peter Bennett responds: You are correct, of course. I'm a bit of a pedant myself. For a certified instrument, the nomenclature should be precise.

However, for this device, the need is to differentiate between MSL and QNH reference while keeping displayed text brief and as large as possible. I believe the compromise achieves that. I hope it doesn't annoy you too much.

Tektronix T-130 article enjoyed

Thanks for a great magazine each month. I always look forward to my

copy. In the June issue, I was particularly interested in the article on the restoration of an old piece of Tektronix gear (siliconchip.com.au/Series/346).

Although retired now, my entire working life was in the field of electronics, so I am familiar with the very respected (and expensive!) Tektronix brand of test equipment. "Built like a tank" with lots of anodised aluminium panels, chassis etc; they were very well made.

The point-to-point wiring in the valve instruments was extremely neat, with bundled cables neatly loom tied. The tag strips were not the usual bakelite strips but specially-made ceramic junction points, plated with silver.

Despite all this professionalism, however, I think that the draftsman responsible for the circuit diagrams must have liked having a bit of fun. If you look carefully at the circuit diagram on pages 36 and 37, next to the bistable multivibrator section, you will see a little cartoon of a fellow tied up in a straitjacket with a weird look on his face.

I've noticed quite a few of these little cartoons in the manuals of other Tektronix equipment.

For example, in a circuit diagram containing a logarithmic amplifier (log amp), there is a drawing of a gardener watering a small tree.

In the circuit for a storage oscilloscope, there is a washerwoman with a bucket, down on her knees with a scrubbing brush, washing the face of the tube. A circuit containing a phase-locked loop had a drawing of a circle with a diagonal slash across it inside a jail cell.

I'm surprised that they allowed these funny little drawings in the manuals of such professional electronic test equipment.

Ray Chapman,
Pakenham, Vic.

Alan Hampel responds: It's good to hear that my article on the T-130 has provided some reading enjoyment. Wait until you see what's in parts two and three!

As indicated in the comments in the bottom right corner, the circuit printed on pages 36 & 37 is not the Tektronix original. The Tek circuit I have is far too tatty with stains and marks to be scanned for inclusion in SILICON CHIP.

As I have an American standard symbol library in my CAD system, I redrew it, emulating the Tektronix style, with some adjustments to make it easier to read when reduced to fit across two pages. And in doing that, I added the waveforms and voltages, which the Tek original didn't have.

That cartoon man is not a Tek original. Perhaps I was a bit cheeky, but I couldn't resist adding a cartoon figure just as Tektronix often did. It seemed to suit how the circuit works.

Incidentally, Tektronix was not unique among American companies in putting cartoon figures on circuits. For instance, I have another manufacturer's circuit for a 1960s computer peripheral which has a little cartoon cat swiping with its paw a part of the circuit. It's a reflection of the 1950s attitude that happy smiling workers are good workers.

Tek instruments were well-built indeed. The same is true for valve-era Hewlett-Packard gear. The English company Marconi use to make some very nice valve-based test gear too. But unfortunately, restoration of old Marconi gear is difficult as they are usually now rusted and corroded. And sometimes with hand-made custom parts made by some chap in the factory who just happened to have considerable skill.

NBN installation a mixed bag

After the NBN box had been installed outside my house, I got a phone call from overseas to tell me that someone will be around to set it up for me. I was told that it would be up and running the same day, that uploads and downloads would be three times faster, and that this extra speed would come at no cost.

When the installer arrived to set up the new modem, which is fed from the white box on the wall outside via RG6 quad shield coax, he found that there was no signal. The call was rebooked for the next week.

A new person arrived and wanted to put 1-inch white conduit up the outside wall, to which I replied: "Why not run it up the inside cavity?" He said that he had never done that before and didn't know how.

I then pulled the white NBN box off the wall to reveal a hole through the mortar where the old twisted-pair cable was. I drilled it out a bit bigger with a half-inch masonry bit and poked a length of orange-tongue up the cavity.

The tech caught on immediately, got up his ladder, retrieved the orange-tongue, taped a length of RG6 to it and slowly feds it down to me.

He then wired and remounted the NBN ODU (outdoor unit). Being young and fit, he had the cable through under the tiles and into the garage, ready for termination with an F-connector to go into the NBN black box. The young tech checked the signal readings on his expensive fancy meter, logged in, entered both serial numbers. And lo and behold, it all worked.

All was well, or so I thought, until I got the next Telstra bill. It had an extra $30 in charges tacked to it, with no warning. I rang them up, but they were not interested in the slightest as to what I had been told over the phone regarding the lack of extra charges.

To end up with a price similar to what I was initially paying, our speed was dropped to about the same speed we initially had with the old ADSL2, around 20Mbps.

Rod Humphris,
Ferntree Gully, Vic.

DRO system for metalworking wanted

I have an idea for a project: a DRO (Digital Readout System) for mill drills; lathes, all sorts of metalworking and woodworking machines. The magnetic strips and readers are readily available; it just needs some 'brains' to run it all. It would be great to get readouts on the X, Y & Z axes and maybe RPM too.

Greg Gifford,
Laguna, NSW.

Response: that is a good idea, but it would need to be designed and tested by someone who has a mill or lathe. The closest we have is a drill press.

Comments on April & May issues

The Editorial Viewpoint in the April 2020 issue on second sourcing (siliconchip.com.au/Article/13630) really hits the mark for the matter of national security. Nostradamus may have been able to foresee problems in the supply of critical parts etc, but our leaders of all political persuasions seem blind to these needs. Unfortunately, I must admit that the government, on behalf of the people, must over-spend to maintain availability of critical parts etc.

Maybe it is an indication of my age, but it seems that many of the components that I use have become obsolete or are heading that way. I am still designing circuits for various applica-

tions and in some cases would like to share them. However, parts availability is always a concern that enters the decision of submitting designs for publication.

I have a very large collection of surplus and recovered components which I use in my designs but which others would not possess. Consequently, if I submit designs using those components, the designs are useless to others. Even when I need to buy a particular component, quite often it must come from overseas, and I must buy many because it is too expensive per component to buy one or two.

Phil Prosser's article in the May 2020 issue on anodising aluminium (siliconchip.com.au/Article/14423) is very nice. I have used lots of aluminium in my designs, both at home and at work, with many work parts being anodised. A few times, I would have liked to anodise my hobby designs but did not have the time to pursue the details, and it was too expensive to be done commercially. Now I can do it if I want. Great!

There is one thing which Phil Prosser did not mention and perhaps does not know. I only know about it because of the problems at work. It was necessary to always have a machine's parts anodised to the same colour and texture. Otherwise, it looks like a patchwork quilt.

Early in the production of the machines, it was discovered that different aluminium alloys produced different anodised shades and textures. It became necessary to specify the same grade of aluminium for all parts. Hopefully, this little fact will prevent people from going wacko when different anodised pieces do not match.

I always find Dr Maddison's articles worth reading. The Grid-Scale Energy Storage (April 2020; siliconchip.com.au/Article/13801) and the Stealth Technology articles are no exceptions (May 2020; siliconchip.com.au/Article/14422).

In many cases, the subject is not of specific interest, but that doesn't matter. As general articles of wide scope and limited depth, they are great windows into areas of technology that I usually would not research. They make me aware of what others are doing and if, by chance, I need technology that has been described in the articles, I know where to start.

Finally, I must comment on Brian Smart's letter that mentioned two boiling kettles with differently charged water. Any competent nuclear physicist knows that there are three kinds of flies: positively charged, negatively charged and those with no charge.

The positively charged flies will be attracted to the negatively charged steam and be annihilated. The negatively charged ones will be attracted to the positively charged steam and be annihilated. The uncharged ones will be unaffected and just fly around, annoying everyone as usual!

George Ramsay
Holland Park. Qld.

Nicholas responds: parts becoming obsolete is a problem. In some cases, we continue to use parts that are no longer manufactured because we can't find modern equivalents. We try to avoid that, though. In most cases, we make sure that all parts specified in our projects are current. However, it's frustratingly common for them to be discontinued soon after we use them in a project, with little-to-no notice, and often with no direct replacement.

That's just a risk that we have to take when designing electronics, I'm afraid. Usually, you have a chance to buy up parts when the manufacturer indicates they will stop making them, so if it's critical, you can try to estimate how many you will need in future and stock up.

VNA guide linked to is incomplete

I found your April 2020 article on the NanoVNA most interesting (siliconchip.com.au/Article/13803), and it prompted me to buy one. However, there is an error in the comments at the end. The URL siliconchip.com.au/link/ab0g is not the complete guide to VNAs as you said, but merely an extract from it, viz: pages 1-168; nonetheless it made for great reading.

Incidentally, the book itself is nearly $300, so you would want to be really keen (as an aged pensioner it's way outside my price range); I'm hoping that there is a cheaper pre-owned one somewhere.

Keep up the great articles!

Dave Horsfall,
North Gosford, NSW.

Comment: it is ironic that a book on how to use VNAs costs more than a VNA! You can also check what library the book can be borrowed from at: https://trove.nla.gov.au/work/237469513 SC

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What came before 3D Printing? Way, way before . . .

SUBTRACTIVE MANUFACTURING

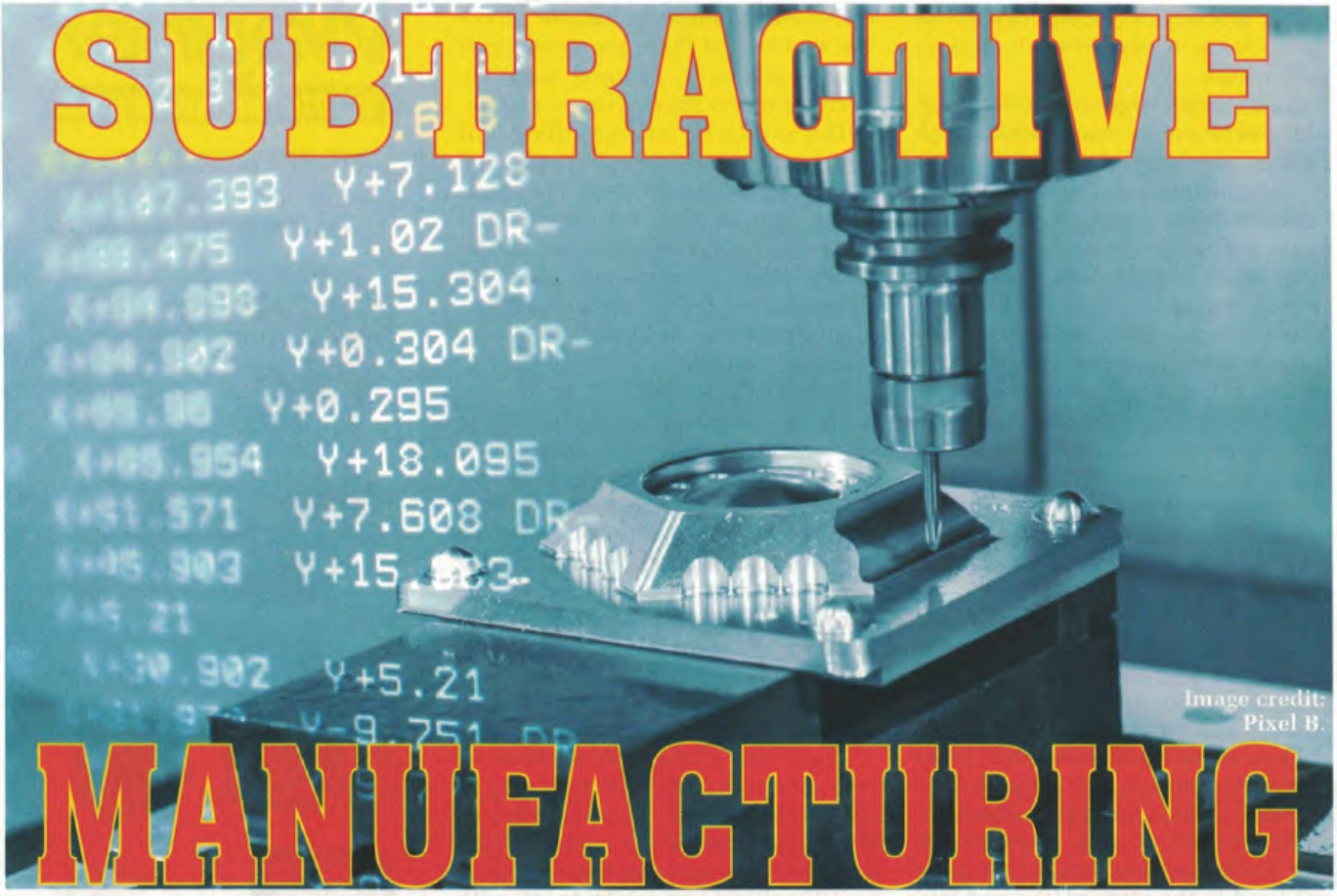

Image credit: Pixel B.

A sculptor creating a statue from a rock by chiselling away unwanted pieces is a classic example of subtractive manufacture, albeit a manual form.

Another such process which will be familiar to many readers is the chemical removal of unwanted copper from blank PCB laminate by the chemical action of ferric chloride or ammonium hydroxide, to produce the desired circuit pattern.

Subtractive manufacturing in a production environment (or increasingly, a home workshop) typically involves using various machine tools. In the past, these were under manual control of an operator, but today are usually under computer control.

This is known as CNC or computer numerical control, or just NC for numerical control when a computer is not used (up until about 1978).

A machine tool is a powered tool, fixed in place, used for shaping various materials that are held by the tool. Basic operations which can be performed with machine tools include turning, boring, milling, broaching, sawing, shaping, planing, reaming and tapping.

The raw materials used as a starting point are typically solid blocks of plastic, metal, timber, composite or ceramics.

The tools used to perform the shaping include lathes, milling machine, broaching machines, pedestal drills, slotters, hand or mechanical saws, shaping machines, grinders or planers. Milling machines have mostly replaced shaping and planing machines.

More recently developed processes to perform the above operations are electrical discharge machining, electrochemical machining, electron beam machining, photochemical machining and ultrasonic machining.

This article discusses subtractive manufacturing processes, with a particular emphasis on techniques and automation.

We'll start with a brief history of subtractive manufacturing machines. The entire history could (and probably does) fill a book!

Lathes, mills etc

In case you don't know the difference between the different types of machine tools, here is a quick rundown. Probably the two most common types are lathes and mills.

A lathe is normally used to work cylindrical objects like logs. They are clamped by one or two sets of jaws which spin the object, then a cutting tool moves along its length and towards the axis of rotation. Items made on a lathe include table legs, vases, chess pieces etc.

A milling machine is similar to a 3D printer in that (at least in its basic form), the object is essentially fixed, and a cutting head moves overhead, dropping down to make cuts into the workpiece.

By moving the cutting head in a zig-zag fashion, it is possible to make a flat surface aligned with the plane of the mill, ideal for placing another item on top of for accurate machining.

by Dr David Maddison

Additive (eg, 3D printing)	Subtractive (machining processes)
Material is added layer by layer	Material is removed from a solid block of starting material, usually in several passes.
Requires suitable materials such as thermosoftening plastic or metal powder	Can be applied to almost any solid material; special techniques are required for extremely hard or brittle materials.
Little or no material is wasted, except for possible small amounts of material used for temporary supports. Scrap materials can be recycled in some cases.	Material that is removed is wasted, although most metals can be recycled.
Shapes of almost infinite complexity can easily be produced, including those with hollows, even if closed-off like a hollow sphere	The complexity of shapes is limited by geometric factors such as the accessibility of an area to a cutting tool. A hollow sphere would be impossible to make subtractively in one piece.
Typically a relatively slow process.	Automated CNC production can be very fast.

Table 1: summary of differences between additive and subtractive manufacturing

Mills can also be used for drilling, by merely inserting drill bits into the tool holder and plunging them into the workpiece.

Drill bits are designed mainly to cut at the tip; other types of milling bits have cutting surfaces on the sides, so they can be moved sideways through the workpiece to make slots and so on.

There is a large variety of milling tools available including end mills, slab mills, hollow mills, ball mills, fly cutters, dovetail cutters, face mill cutters, bevel angle cutters and so on. They suit different types of material and making different sorts of cuts.

Differences between additive and subtractive manufacturing

There are important differences between additive and subtractive manufacturing processes and so neither process can fully replace the other. These differences are outlined in Table 1.

The main differences are in the types of materials that can be used, the shapes that can be made, the amount of waste that is produced and the speed with which items can be made.

History of subtractive manufacturing

Lathes, which enabled the production of axially symmetrical parts such as pots and vases, have been known since ancient times.

But precision parts such as steam engine components (eg, pistons) could not be made on such machines due to their limited precision and accuracy.

In 1774, John Wilkinson developed the first waterwheel-powered horizontal boring mill. This enabled him to supply James Watt and Matthew Boulton with accurately bored cylinders for their steam engines in 1776.

For the first time, these had minimum leakage due to the accuracy of the bore.

Unlike previous boring machines, the bar that supported the boring bit was supported at both ends, the workpiece having previously had a hole drilled through it. This provided an accurate bore in terms of diameter, straightness and roundness.

Wilkinson's machine is regarded by many industrial historians as the first machine tool and was a critical development for the progress of the Industrial Revolution. Later models of the boring machine were powered by steam engines, whose cylinders were made by the machines they were powering!

This led to the development in 1794 of the first engine-powered lathe by Henry Maudsley, which was later developed into a screw-cutting lathe in 1800.

The availability of the steam engine to power machines led to the development of other machine tools such as the planer, invented by Richard Roberts in 1817 and the horizontal milling machine, invented by Eli Whitney in 1818 (Fig.1).

An early use of precision machine tools was Eli

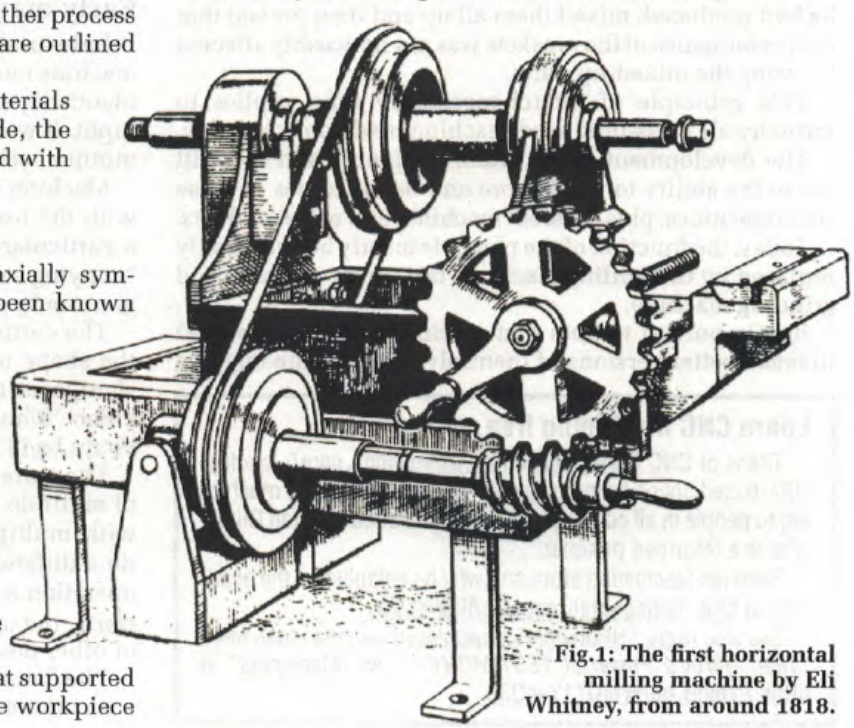

Fig.1: The first horizontal milling machine by Eli Whitney, from around 1818.

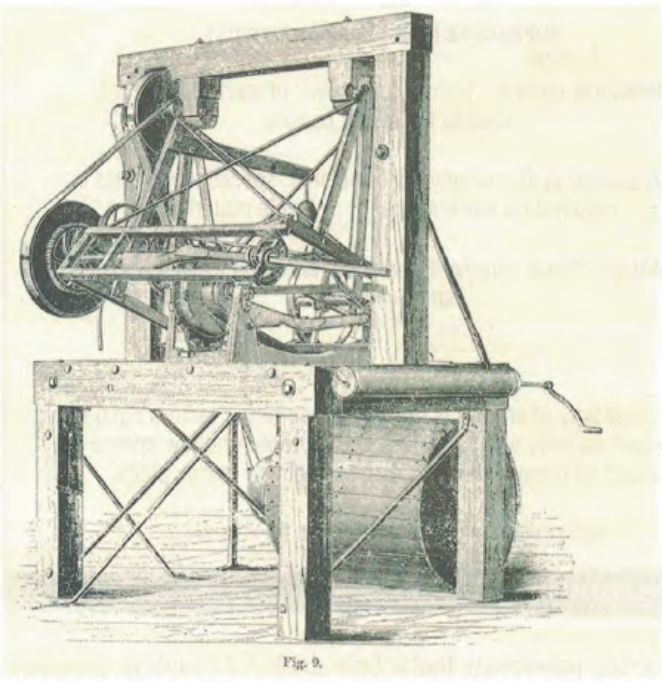

Fig.2: a drawing of Thomas Blanchard's original copying lathe of 1818, with a photo of a later development of that machine made in Chicopee, Massachusetts and sold to the British Government in the 1850s. It was used at the Enfield Armory for the next 100 years.

Whitney's manufacture of muskets for the US government. At the time, parts for devices like firearms and steam engines were custom-made for the individual unit, and were not interchangeable.

Whitney's idea to win a US Government contract was to produce firearms with interchangeable parts using a precision lathe and milling machine. This would lower costs and reduce the necessity for highly-skilled machinists, who were in short supply at the time.

The experts did not believe this was possible, so he went to Washington DC in 1791 and took the parts of ten muskets he had produced, mixed them all up and then proved that the performance of the muskets was not noticeably affected by using the mixed-up parts.

This principle of interchangeability now applies to virtually all mass-produced machine-made objects today.

The development of the lathe, the planer and the mill led to the ability to make more and better copies of these same machines, plus different machines and more products.

Today, the function of the planer is mostly but not totally replaced by the milling machine, broaching machine and grinding machine.

It is important to note that machine tools can be used to make better versions of themselves, hence the ongoing improvement in the quality and precision of such tools.

Machines were typically powered by a water wheel before 1775 and steam engines from about 1775 (many made by Boulton & Watt, a partnership between James Watt's company and the engineering firm of Matthew Boulton).

Nikolaus Otto produced four-stroke gasoline stationary engines from 1876 to power lathes and other small machines, although some coal-gas powered internal combustion engines preceded that.

Electric motors were also used from about 1890.

Early machine tool automation

Industrial mass-production required ways to control machine tools that would enable hundreds or thousands of identical parts to be produced with minimal or no manual input. It was also desirable to be able to alter designs with minimal effort.

Machine tool automation started in the 19th century with the use of cams to move parts of a machine tool in a particular sequence. Thomas Blanchard developed the "copying (or duplicating) lathe" in 1818, for reproducing gun stocks and any other irregular shape in wood (Fig.2).

The cutting tool was guided by a cam that represented the shape to be cut. It was regarded as one of the most significant tools in American industrial history. See the video "*Blanchard Lathe at Asa Waters Mansion*" at **https://youtu.be/ITNEHqW0hyQ**

The turret lathe is designed for automatic production of multiple duplicate parts using an indexing tool holder with multiple different cutting tools, each designed to do a different job (Fig.3). When one part of a machining operation is finished, before the next part of the operation starts, the tool holder is rotated to the next tool by a cam or other mechanism.

The first turret lathe was built by Stephen Fitch in 1845, with others making similar designs around the same time.

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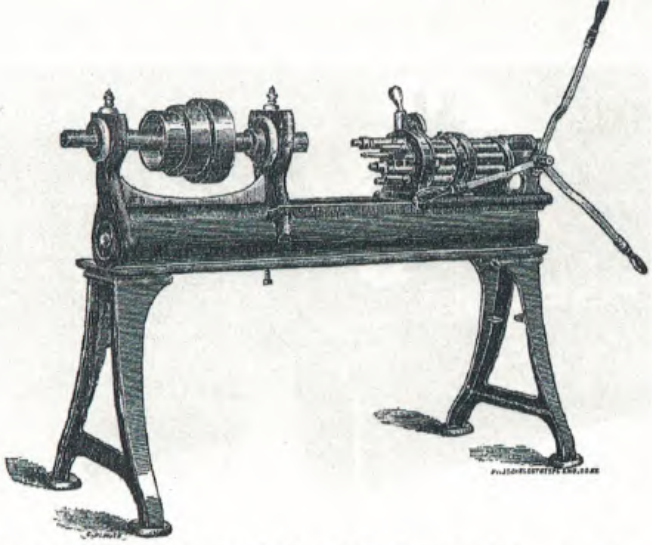


Fig.3 (above): the turret lathe of Stephen Fitch from 1845 from "Report on the Manufactures of Interchangeable Mechanism" US Government Printing Office, p.644, 1883 (siliconchip.com.au/link/ab0u). The indexed head with different cutting tools is still used today.

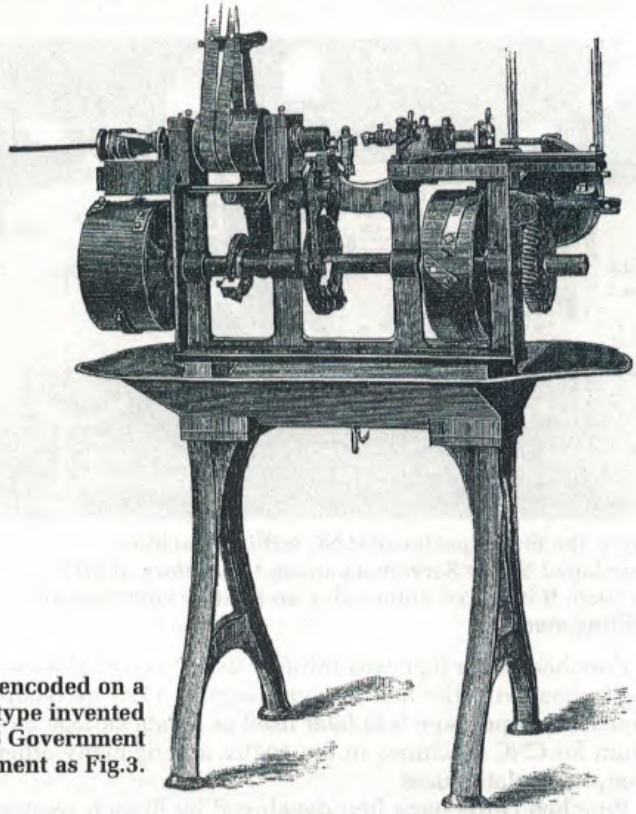


Fig.4 (right): a "brain wheel" (instructions encoded on a cam) on a screw-making turret lathe of the type invented by Chris Spencer in 1873. From the same US Government Printing Office document as Fig.3.

In 1873, Chris Spencer of New England, USA patented the first automatic lathe, but he failed to patent a vital component which he called the "brain wheel". That was a cam that coded 'instructions' for movement of the tools on the lathe, and others quickly took up the idea (Fig.4). The "brain wheel" can still be found on some mechanically-controlled automatic lathes today.

The beginning of numerical control

These earlier automated machining approaches using templates or cams made it relatively difficult to change the "program", since new templates or cams had to be produced.

The modern era in subtractive manufacturing started in the 1940s with the introduction of numerical control or NC.

It was then relatively easy to change the program because early NC programming used punched cards, paper or magnetic tape to control servomotors which operated machine tools.

Changing the program on the punched cards or tape was easy compared to making a new template or cam. There were earlier programmable machines such as the Jacquard loom, which used punched cards, but this technology was never applied to machine tools.

Early NC machines were connected to computers as soon as they became available, and today the process is fully computerised and known as CNC (computer numerical control).

Important CNC inventions

Before NC and CNC could be developed, certain enabling technologies that had to be invented first. These include punched paper tape, punched cards, magnetic tape, the ball screw and servo motors.

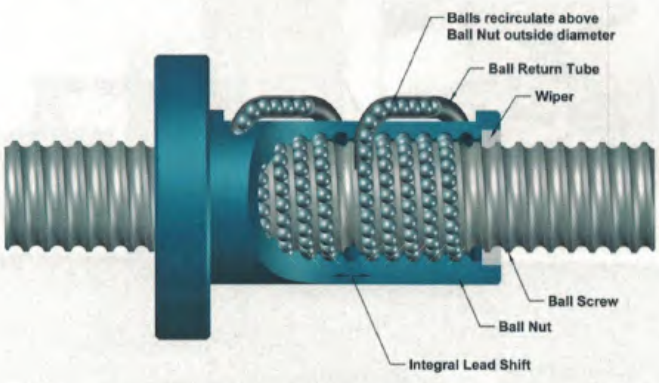


Fig.5: a ball screw with external ball return as used on CNC machines, to precisely convert rotary motion into linear motion. The balls are the only contact surfaces between matching helical grooves. There are several variations of this design. *Source: Barnes Industries, Inc.*

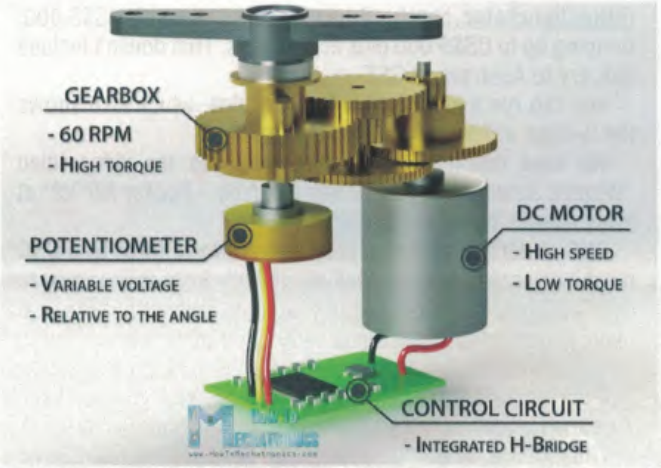
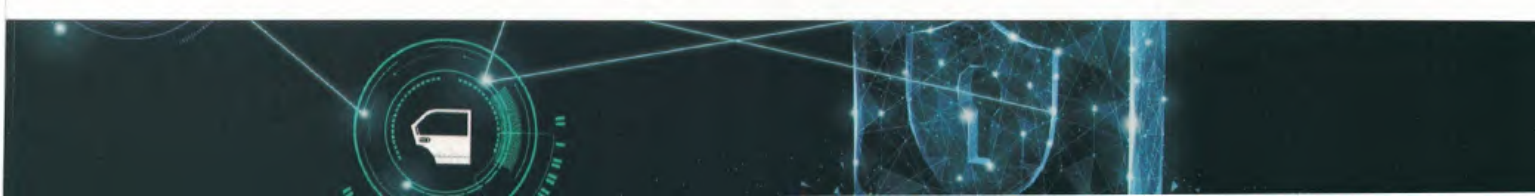


Fig.6: the elements of a simple hobby servo motor. Screengrab from the video "How Servo Motors Work & How To Control Servos using Arduino" at https://youtu.be/LXURLvga8bQ



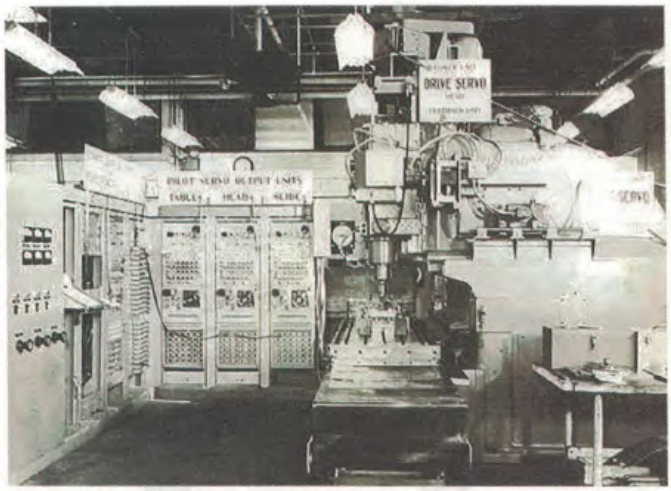


Fig.7: the first experimental NC milling machine, developed by the Servomechanism Laboratory at MIT in 1950. It involved automating an existing commercial milling machine.

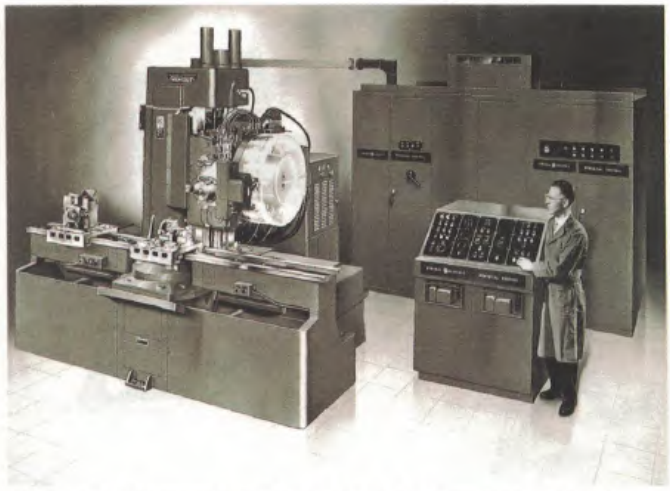


Fig.8: the Kearney & Trecker Corp. Milwaukee-Matic II from 1958.

Punched paper tape was initially used to control weaving looms, with the first known usage in 1725 by Basile Bouchon. Paper tape was later used as a data storage medium for CNC machines in the 1970s, among many other computer-related uses.

Punched cards were first developed by French weaver Joseph Marie Jacquard in 1804 to control weaving looms by encoding the pattern that was to be woven.

In 1890, a punched card system was developed by Herman Hollerith at MIT (Massachusetts Institute of Technology) for encoding and analysing data from the US Census in the new science of data processing.

He founded a firm which became a part of IBM, and the cards were known as Hollerith cards.

Punched cards were also used in computers associated with early CNC.

Magnetic tape was invented in Germany in 1928, and was used to record analog and later digital signals. Tapes were used in the first commercially-successful CNC machines.

Paper tape was often used in early NC machines because the reader was smaller and less expensive than punched card or magnetic tape readers.

Rudolph Boehm invented the precision ball lead screw in Texas in 1929. He called it an "antifriction nut" (see siliconchip.com.au/link/ab0t and Fig.5).

This is not vital for CNC machines, but it is a highly desirable and precise method to convert rotary motion into linear motion with minimal friction and play, with much less maintenance than the traditional Acme screw.

A servo motor is a rotary or linear actuator that provides accurate rotary or linear position placement. It comprises an electric motor, a sensor to detect the position and a controller. When the appropriate signal is sent to it, it moves to the commanded position (Fig.6).

Servo motors are responsible for various motions of CNC machines.

Parsons, Sikorsky and MIT

The origins of modern NC are usually attributed to John Parsons and Frank Stulen of Parsons Corp in Michigan,

The smallest and cheapest CNC machines

One of the cheapest five-axis CNC mills is the PocketNC (https://pocketnc.com/). Prices start at around US$6,000, ramping up to US$9,000 plus accessories. That doesn't include delivery to Australia or GST.

You can run a simulator of this machine, which also shows the G-code, at https://sim.pocketnc.com/

We have not tested this ourselves. See the video titled *"World's Smallest 5 Axis Milling Machine - Pocket NC V2"* at https://youtu.be/vMY06dzf7UA

CNC routers (often incorrectly referred to as three-axis CNC machines), can be bought relatively cheaply from online sources such as eBay. They start at a few hundred dollars, but they are really only suitable for working with softer materials.

Some will apparently machine aluminium, but do so slowly. See the video titled *"Sainsmart 3018 PROVer Mini Cnc Build, Test and Review"* at https://youtu.be/fT8dv1Eanps

The video author says it is good for wood, acrylic, PCBs and aluminium. The manufacturer's website can be viewed at siliconchip.com.au/link/ab0x

Fig.9: a Knuth KSB 40 CNC drill press for drilling, reaming and thread cutting. A typical workpiece is shown inset above.

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Fig.10: a Giddings and Lewis milling machine attached to a Numericord numerical control system around 1955. The magnetic tapes it used were prepared elsewhere on the Numericord Director.

USA. In 1942, the Parsons company became involved in the production of helicopter rotor blades for Sikorsky.

Sikorsky sent the shape of the ribs in the form of 17 coordinate points which defined the outline. The space between the points had to be interpolated with French curves.

The original manufacturing process as required by Sikorsky had deficiencies, so it was decided to stamp the ribs from metal rather than build them with trusses. The 17 coordinate points were interpolated to make 200 points using an IBM 602A punched-card calculator, and these were tabulated and used to guide, by hand, on a milling machine, a cutting tool to make the stamping die.

One person controlled the X-axis and the other the Y-axis, to guide the milling machine in a straight line between the 200 points; enough to emulate the desired curve. This was NC but with humans rather than machines providing the guidance!

Parsons then had the idea for a fully automated machine, but had trouble getting people interested. Then in 1949, the US Air Force funded Parsons to build machines.

His early ones had problems related to the requirement for a feedback mechanism to control power to the cutting head. Otherwise, it made rough cuts, as the cutting forces changed as the direction changed, so the power had to be adjusted.

This feedback mechanism turned out to be a very important development for CNC.

Parsons approached the MIT Servomechanisms laboratory, and they became involved in the project to build a better machine based on Parsons' ideas.

They automated an existing commercial Hydrotel milling machine using vacuum tube electronics and a tape reader in 1950 (Fig.7).

A remarkably advanced machine from Hughes Products in 1958

There is a video showing an early CNC machine operation from 1958 titled *"The History of Numerically Controlled Machine Tool - NC and CNC"* at **https://youtu.be/TdoaHK5TRh8**

All the essential elements of a modern CNC system are present, except perhaps the CAD software to design the part.

CNC machine languages

APT

APT or Automatically Programmed Tool is a computer language developed under the leadership of Douglas T. Ross of MIT in 1956. It and its derivatives are still in use today.

The language defines the path a cutting tool must follow using sets of coordinates (see listing 1). The program output is converted into a CL or Cutter Location file, which controls the machine.

This latter control code is often produced in a standardised set of instructions defined by RS-274, known as G-code.

APT can be regarded as a high-level English-like language that produces the lower level G-code that provides instructions for the machine.

It is also possible to directly program in G-code for those so interested; however, most modern computer-aided design (CAD) packages can turn a three-dimensional model directly into the required G-code instructions for the CNC machine.

Such programs are known as G-code generators. G-code can be used for additive manufacture (eg, 3D printing) as well.

Listing 1:

```
PARTNO / APT-1
CLPRNT
UNITS / MM
NOPOST
CUTTER / 20.0

$$ GEOMETRY DEFINITION
SETPT = POINT / 0.0, 0.0, 0.0
STRTPT = POINT / 70,70,0
P1 = POINT / 50, 50, 0
P2 = POINT / 20, -20, 0
C1 = CIRCLE / CENTER, P2, RADIUS, 30
P3 = POINT / -50, -50, 0
P5 = POINT / -30, 30, 0
C2 = CIRCLE / CENTER, P5, RADIUS, 20
P4 = POINT / 50, -20, 0
L1 = LINE / P1, P4
L2 = LINE / P3, PERPTO, L1
L3 = LINE / P3, PARLEL, L1
L4 = LINE / P1, PERPTO, L1
PLAN1 = PLANE / P1, P2, P3
PLAN2 = PLANE / PARLEL,
        PLAN1, ZSMALL, 16

$$ MOTION COMMANDS
SPINDL / 3000, CW
FEDRAT / 100, 0
FROM / STRTPT
GO/TO, L1, TO, PLAN2, TO, L4
TLLFT, GOFWD / L1, TANTO, C1
GOFWD / C1, TANTO, L2
GOFWD / L2, PAST, L3
GORGT / L3, TANTO, C2
GOFWD / C2, TANTO, L4
GOFWD / L4, PAST, L1
NOPS
GOTO / STRTPT
FINI
```

G-code

G-code (for geometric code) is the low-level command set that provides instructions to perform motion procedures, such as moving the workpiece and cutter in the desired path. A list of typical G-code commands is shown in Table 2. G-code comes in various "dialects", which are slight variations according to the manufacturer.

G-code is written in the form of commands which start with a letter and are followed by a number.

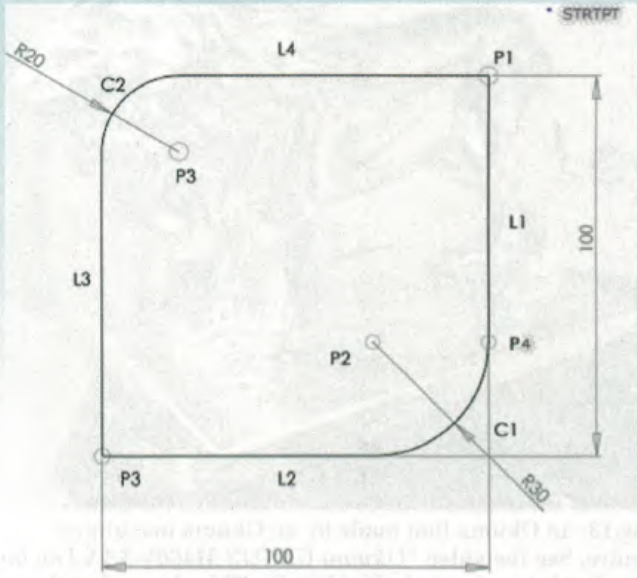
The letters stand for:

- N: line number
- G: motion and function
- X, Y, Z: position
- F: feed rate
- S: spindle speed
- T: tool selection
- M: miscellaneous functions.
- I, J: incremental centre of arc
- R: radius of arc

Using the above form, an example of a G-code program line provided by Autodesk is G01 X1 Y1 F20 T01 M03 S500. This will generate a linear feed move G01, to position 1,1 with a feed rate of 20, tool 01, spindle on CW rotation and spindle speed 500. (See Table 3 for M-codes.)

Table 2 – example G-codes

G00 Rapid traverse (positioning)
G01 Linear interpolation (eg, feed in a straight line)
G02 Clockwise movement (CW)
G03 Counterclockwise movement (CCW)
G04 Pause or dwell
G17 Select X-Y plane
G20 Imperial format (inch)
G21 Metric format (mm)
G28 Return to machine zero
G40 Tool cutter radius compensation off
G43 Apply tool length compensation
G54 Work coordinate system
G80 Cancel canned cycle
G90 Use absolute dimensions
G91 Use incremental coordinates
G92 Set the origin
G94 Feed rate



The shape defined by the APT program listing of Listing 1 (Wikipedia).

Apart from G-code, there is also M-code (Table 3), where M stands for miscellaneous. While G-code instructions tell a CNC machine where and how to move, M-code instructions are for miscellaneous functions such as starting the cutter or turning coolant on or off. These instructions are incorporated into the overall program code.

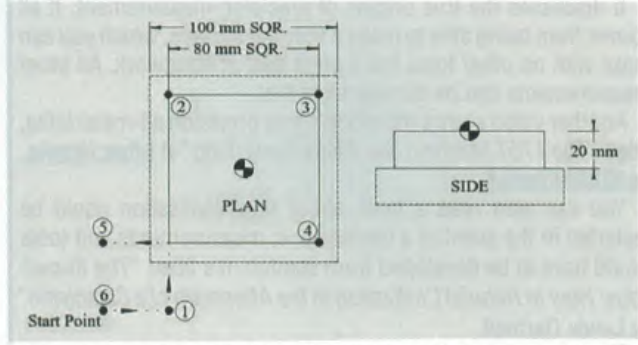
Table 3 – example M-codes

M00 Program stop
M02 End of program
M03 Spindle clockwise rotation
M04 Spindle anti-clockwise rotation
M05 Spindle stop
M06 Tool change
M08 Coolant on
M09 Coolant off
M30 End of Program, rewind and reset modes

A sample of a more sophisticated G-code program, courtesy of HelmanCNC, is shown in Listing 2. Note that program code structure is a little different than the one-liner above. The part produced by this code is shown below.

Listing 2:

```
\O1000
T1 M6
(Linear / Feed - Absolute)
G0 G90 G40 G21 G17 G94 G80
G54 X-75 Y-75 S500 M3 (Position 6)
G43 Z100 H1
Z5
G1 Z-20 F100
X-40                (Position 1)
Y40 M8              (Position 2)
X40                 (Position 3)
Y-40                (Position 4)
X-75                (Position 5)
Y-75                (Position 6)
G0 Z100
M30
```



The part produced by the simple G-code program shown in Listing 2.

Fig.11 (above): a Knuth Turnstar 300C horizontal CNC lathe for mass production. You can see the control screen, the chuck to hold the workpiece, the tool holder to the right of the chuck and coolant nozzles with orange tips.

Fig.12 (right): an Okuma Genos M460V-5AX entry-level five-axis machining centre. Its capabilities include workpiece size of up to 600mm diameter, 400mm height and 300kg weight, a tool magazine with a capacity of 48 tools, spindle speed up to 15,000rpm and a power of 22kW. It weighs 8,300kg.

Then Parsons was locked out of the work, despite it being his idea! Many of the team left after this, and in 1955, they went on to develop the Numericord NC system, and other companies started producing NC systems as well. By 1955, several NC machines were on display Chicago Machine Tool Show (Fig.10).

This led to the development of the first commercial NC machining centre with an automatic tool changer and workpiece positioning, the Kearney & Trecker Corp. Milwaukee-Matic II of 1958 (Fig.8).

You can view a very satisfying original promotional video titled *"The Numerically Controlled Machining Center 1950s Educational Documentary"* at **https://youtu.be/Y3YrbEGWE04**

The origins of precision machining and measurement

There is an interesting video titled *"Origins of Precision and first project introduction"* at **https://youtu.be/gNRnrn5DE58**

It discusses the true origins of precision measurement. It all comes from being able to make a very flat surface, which you can make with no other tools but a great deal of handwork. All other measurements can be derived from that.

Another video shows the world's first precision all-metal lathe, titled *"The 1751 Machine that Made Everything"* at **https://youtu.be/djB9oK6pkbA**

You can also read a book about how civilisation could be restarted in the event of a catastrophe; measurements and tools would have to be developed from scratch. It's titled *"The Knowledge: How to Rebuild Civilization in the Aftermath of a Cataclysm"* by Lewis Dartnell.

There is a related video, *"How to rebuild the world from scratch | Lewis Dartnell"* at **https://youtu.be/CdTzsbqQyhY**

Conventional and unconventional machining processes

Virtually all machining processes can be automated with CNC technology, but processes where material is removed by mechanical force are generally considered 'conventional', while those which use little or no mechanical forces are 'unconventional'.

The conventional machining processes most commonly used with CNC include the lathe, the milling machine and

Fig.13: an Okuma lion made by an Okuma machining centre. See the video *"Okuma GENOS M460V-5AX Leo the Lion"* at https://youtu.be/A49l8ljcPis This shows that the machining process is much like the inverse of an additive process like 3D printing.

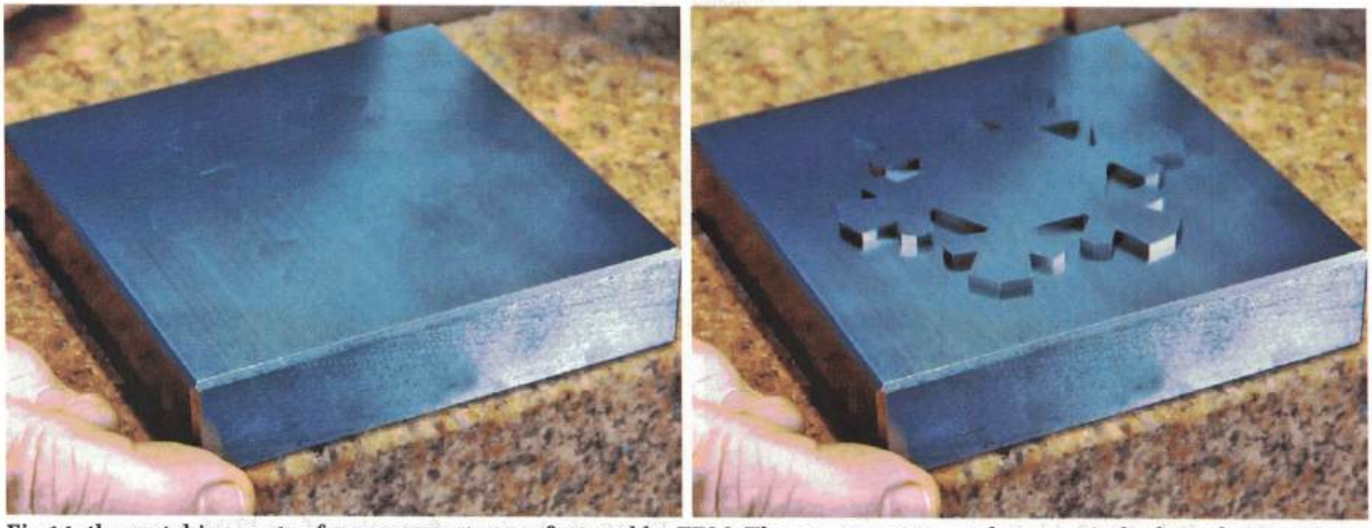


Fig.14: the matching parts of a component manufactured by EDM. The components match so precisely that when one is inserted within the other, the boundary between the two is almost invisible. Source: Reliable EDM.

the drill. Of these, the milling machine is the most versatile. A milling machine with CNC controls is usually referred to as a "machining centre" (see Fig.12).

Electrical discharge machining (EDM): electrical energy is used to remove material from a conductive workpiece. This is often used for hard metals which are otherwise difficult to machine (see Figs.14-16).

In operation, the workpiece and electrode are immersed into a dielectric fluid and the electric field increased until dielectric breakdown occurs, resulting in melting and vaporisation of the desired workpiece material.

No mechanical stress is applied, but heat is generated, which may affect the material being machined. Excellent surface finish can be achieved.

Electrochemical machining (ECM): electrolysis is used to remove material and so, in a sense, this is

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Tariff Super Clock (Jul18 – siliconchip.com.au/Article11137)
Altimeter & Weather Station (Dec17 – siliconchip.com.au/Article/10898)
Radio IF Alignment (Sep17– siliconchip.com.au/Article/10799)
Deluxe eFuse (Jul17 – siliconchip.com.au/Series/315)
DDS Signal Generator (Apr17 – siliconchip.com.au/Article/10616)
Voltage/Current Reference (Oct16 – siliconchip.com.au/Series/305)
Energy Meter (Aug16 – siliconchip.com.au/Series/302)
Super Clock (Jul16 – siliconchip.com.au/Article/9887)
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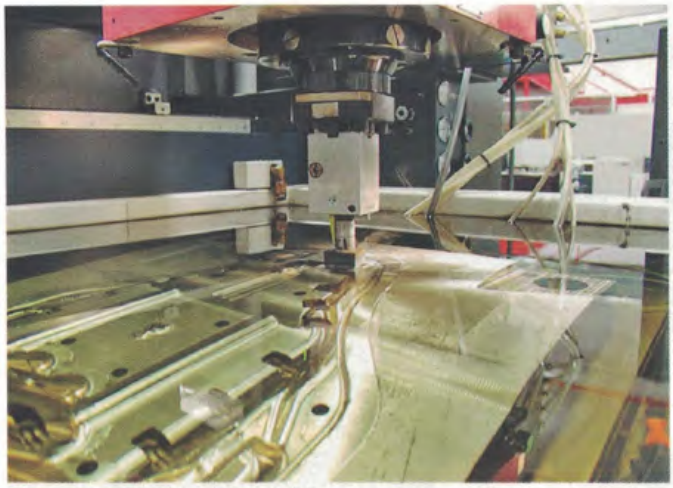


Fig.15: an EDM machine. Note how the workpiece is immersed in a dielectric fluid. *Source: NezzerX.*

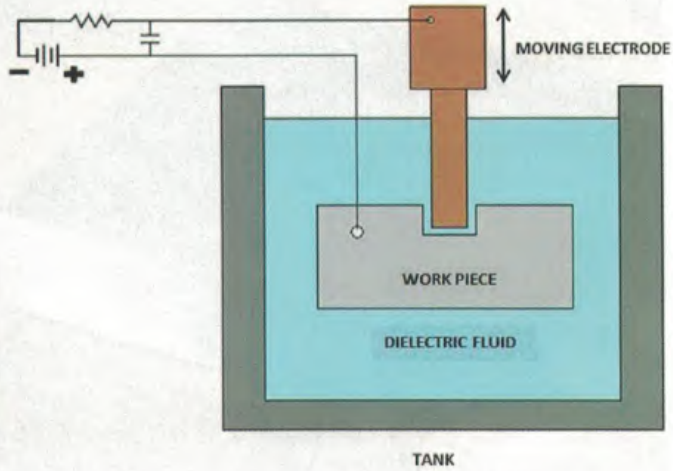


Fig.16: the basic configuration of an EDM system.

the opposite of electroplating. The workpiece is attached to a positive power source and the tool used for removal of material, the negative power source.

ECM can be used to produce small holes accurately and for 3D micromachining (see Fig.18).

Electron beam machining (EBM): a high-energy electron beam in a vacuum chamber removes material from a workpiece by vapourisation (Figs.17&19).

The electron beam can be controlled very accurately, to within about 0.002mm.

Hard or heat-resistant materials can be machined, and the beam is extremely accurate, but it is relatively slow and only really suitable for removing small amounts of material. Also, the equipment is expensive.

Applications include drilling holes in synthetic jewels for the watch industry, welding small pieces of refractory metals, drilling cooling holes in aerospace gas turbines or space nuclear reactors, and drilling small holes in wire-drawing dies.

Laser beam machining (LBM): a laser beam vaporises material from the desired area (Fig.20). Tiny feature sizes can be produced, a wide range of materials can be machined, there is no tool wear and machining times are rapid.

But longer holes tend to be tapered, blind holes of a specified depth are hard to achieve, and the maximum material thickness is restricted to about 50mm.

Photochemical machining (PCM): chemicals and a photoresist material are used to etch a workpiece selectively.

A simple example is the selective removal of copper from a blank PCB.

A pattern is photographically printed onto a surface to be machined using a photoresist layer, and unexposed parts of the workpiece are then removed with an etchant chemical.

Highly-detailed parts can be produced such as circuit elements, grids for batteries, optical encoders, jewellery, signs etc.

Ultrasonic machining: a cutting tool vibrates at a high frequency (18-40kHz) with a low amplitude (0.05-0.125mm) in the presence of an abrasive slurry to remove material.

This is useful for machining brittle materials such as ceramics; however, the material removal rate is low, and the tool or "sonotrode" is subject to wear.

Ultrasonic machining is suitable for substances such as glass, sapphire, alumina, ferrite, polycrystalline diamond, piezoceramics, quartz, chemical vapour deposited silicon carbide, ceramic matrix composites and technical ceramics.

Abrasive jet machining (AJM): small abrasive particles are suspended in a stream of air and directed at the workpiece at a high pressure to remove the desired material. The process is suitable for brittle or soft materials, and good cutting accuracies can be achieved. There is minimal surface damage.

Abrasive water-jet machining (AWJ): similar to AJM but using water instead of air; almost any material can be cut with no heat damage to the workpiece (see Fig.21).

DIY machining projects

There are lots of websites devoted to DIY CNC machining, including converting existing equipment such as lathes or mills for computer control.

One video describes a DIY water jet cutter. It is titled *"Waterjet cutter built with a cheap pressure washer"* and can be viewed at **https://youtu.be/Lg_B6Ca3jc**

Note that such a machine could be quite dangerous to operate.

A video describing DIY electrical discharge milling can be found at: *"Drill through anything (conductive) with Electrical Discharge Machining"*, at **https://youtu.be/rpHYBz7TolI** (also see photo opposite). Again, this involves significant hazards.

Fig.17 (above): a combustion chamber component made by an electron beam machine manufactured by PTR Strahltechnik GmbH. The material thickness is 1.1mm, and there are 3748 0.9mm-diameter holes. It took one hour to make.

Ice-jet machining (IJ): was developed as it is difficult to filter out and reuse abrasive particles from a water jet. So this is like AWJ, but as ice is used as the abrasive medium, used water can be re-frozen and re-used.

Plasma cutting: used by some CNC machines to cut sheet metal, plate or pipes. An electrically ionised and conductive gas, a plasma, is created between the workpiece and the cutting torch and the electric arc established melts or vapourises the material that is to be cut.

A compressed gas is used, and as it passes through the cut area, it blows away molten or vapourised material.

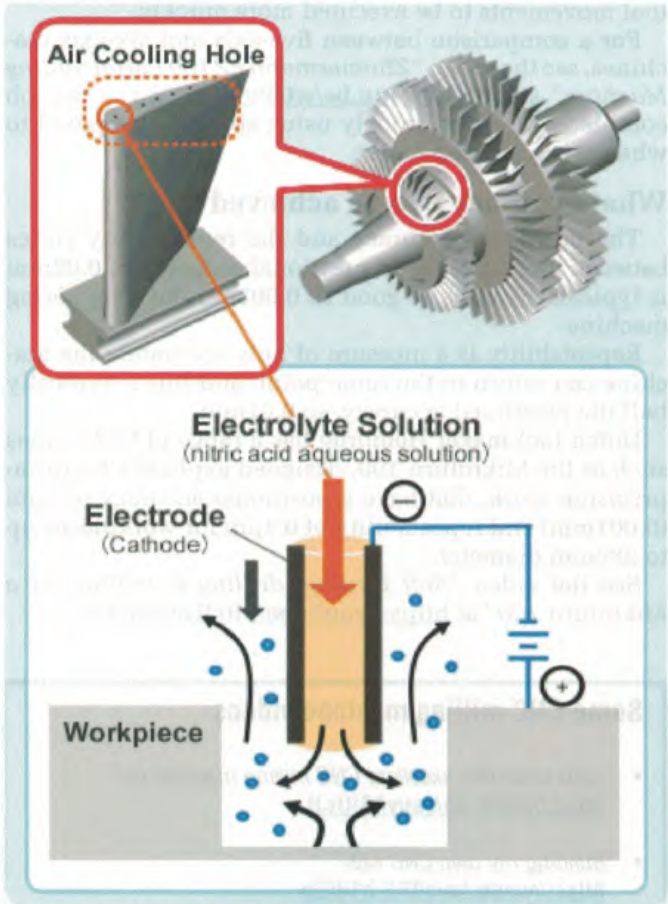


Fig.18: the electrochemical machining of cooling holes in a nickel-alloy gas turbine blade. Nitric acid is used as the electrolyte solution, and the machining electrode (cathode) is made of a titanium alloy, machined to exact dimensions. A high current passes between the workpiece and the machining cathode, resulting in the dissolution of the workpiece material. *Source: Tokyo Titanium Co., Ltd.*

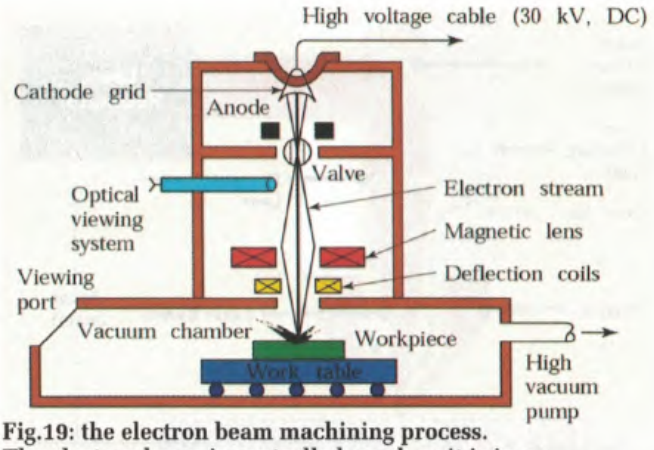


Fig.19: the electron beam machining process. The electron beam is controlled much as it is in a conventional cathode ray tube (CRT). The entire electron gun mechanism and workpiece chamber are held under vacuum, because the electron beam will not travel through air.

The Maslow open-source CNC machine

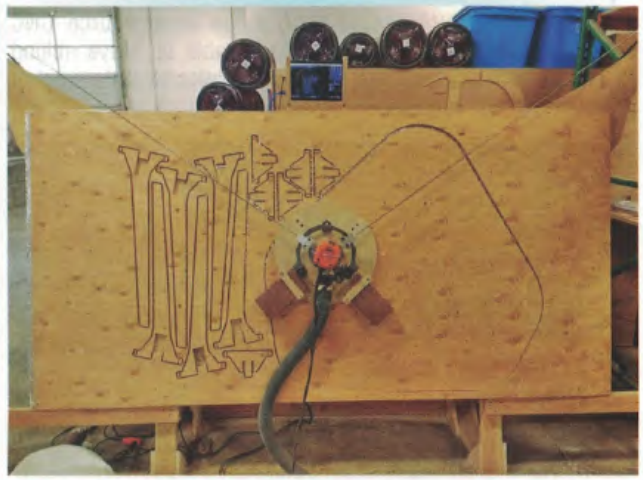
The Maslow (www.maslowcnc.com) is a DIY, open-source CNC machine able to cut out large flat sheets of soft, thin materials such as timber or plastic up to 1.2m x 2.4m (the size of a standard sheet of plywood) – see photo below.

The manufacturer suggests applications such as building a "tiny house, a kayak, a tree house, some furniture, or anything else you can imagine". It is unique in that it is vertically orientated and only about 1m deep, so it occupies relatively little floor space.

The free software and designs work with Mac, Windows or Linux. (Some support plans require payment.) Note that the basic kit does not include all the parts such as timber pieces, a router and possibly other components. Please do your own research if you want to build it. See the video titled *"Maslow CNC Introduction Video"* at https://youtu.be/gtJ5Z3phDhs

You would have to find a seller that ships to Australia. One that we found (but did not purchase from) sold a basic kit for US$399 plus US$80 delivery to Melbourne.

See siliconchip.com.au/link/ab0y



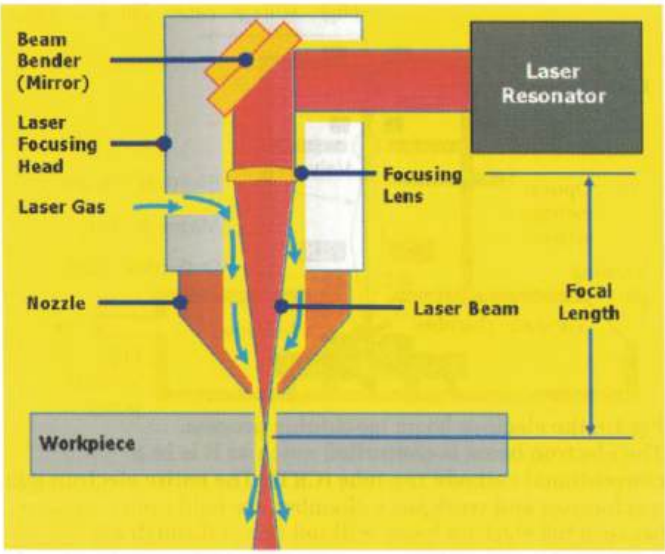


Fig.20: the configuration of a typical laser cutter, a type of laser machining device. The workpiece and/or the laser can be moved under computer control to cut the desired pattern. LBM is good for sheet metal parts, making holes from 0.005mm to 1.3mm, cut-outs of various shapes, features in silicon wafers for the electronics industry and thin or delicate parts.

Number of axes for CNC machining

CNC machines are partly characterised by the number of axes they have, which is usually between two and five, but possibly more. A two-axis machine cuts only in the one plane using two axes, X and Y. An example of this would be a basic laser cutter.

A 2.5-axis machine also cuts in one plane, but the height can be changed in the Z-axis direction (not simultaneously with X and Y movements). Examples are a very basic milling machine or a drilling machine.

A three-axis machine can simultaneously move the cutting tool in three directions, X, Y and Z. A true four-axis machine adds rotary movement around the X-axis, referred to as the A axis. This rotation allows the material to be cut around the B-axis.

A five-axis machine allows extremely complex modes of movement, with two axes of rotation (A & B, B & C or A & C) around the X, Y and Z axes.

Some milling machines are available with six or more axes, but the five-axis type is the most common. Extra axes beyond five allow certain transitions to new positions and tool movements to be executed more quickly.

For a comparison between five-axis and six-axis machines, see the video *"Zimmermann FZ100 Portal Milling Machine"* at https://youtu.be/wOPt0dMP6ZA – the job completes far more quickly using six axes compared to when it is restricted to five.

Open source CNC software

LinuxCNC (http://linuxcnc.org/) is an open-source CNC software suite. It is described as being able to "drive milling machines, lathes, 3d printers, laser cutters, plasma cutters, robot arms, hexapods, and more".

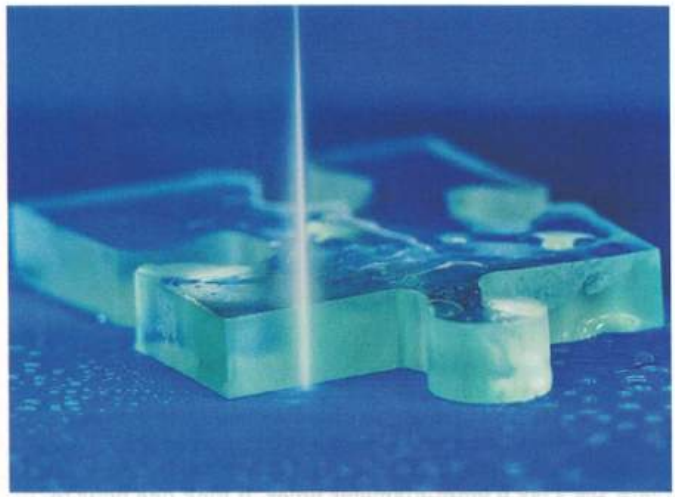


Fig.21: glass is a difficult material to machine by normal methods. Here it is being cut with abrasive water jet machining. *Source: Water Jet Sweden AB.*

What accuracy can be achieved?

The positional accuracy and the repeatability varies between machines, but a positional accuracy of 0.02mm is typical; it can be as good as 0.003mm for a jig boring machine.

Repeatability is a measure of how accurately the machine can return to the same point, and this is typically half the positional accuracy, so 0.01mm.

Dutch tool maker Hembrug has a range of CNC lathes such as the Mikroturn 100, designed explicitly for ultra-precision work, that have a positional accuracy of 1µm (0.001mm) and repeatability of 0.1µm for workpieces up to 380mm diameter.

See the video *"Soft turning, drilling & milling on a Mikroturn 100"* at https://youtu.be/MtrJDBBmONo

Some CNC milling machine videos

- *"Look what this excellent CNC milling machine do"* https://youtu.be/peuvASjUsJI
- *"Building my own CNC Mill"* https://youtu.be/q0RE-h1VDIg
- *"Fastest CNC Lathe Machine Working"* https://youtu.be/W0E1aX6vVWw
- "5 Axis OneCNC CAD CAM CNC Turbine Blade Manufacture" https://youtu.be/Vk_IhNTO6z8

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N 2097

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T 2694A

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30W Lithium 'Go Anywhere' Soldering Iron

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INCLUDES ACCESSORY PACK: • 3 tips: conical, hot knife/3D print finishing tool, hot air • Micro USB cable • Solder container & 1m of solder • Tip sponge.

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Quality Resin Core Solder

Premium grade for leaded soldering. 200gm reels. 60% tin, 40% lead.

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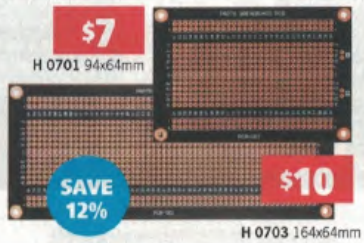

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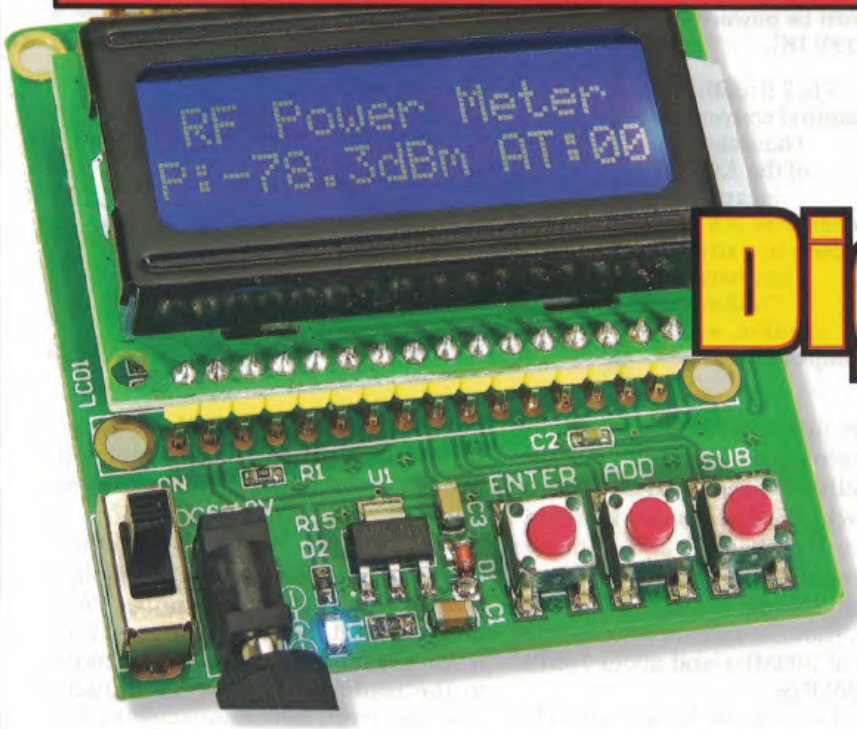


A TINY Digital RF Power Meter

Would you like to measure the RF power output from oscillators or low power transmitters operating at frequencies between 100kHz and 500MHz?

This very small module from Banggood (China) will let you do just that. It has a 16x2 LCD readout and gives quite accurate readings for signals between +16.0dBm (40mW) and -75dBm (32pW).

All for less than $50!

Back in the October 2008 issue of SILICON CHIP, we described a Digital RF Level and Power Meter project.

It used an Analog Devices AD8307AN logarithmic amplifier/detector IC at the input, followed by a digital metering circuit with a programmed PIC 16F88 microcontroller (MCU) driving a 16x2 LCD readout.

The frequency range was from below 50kHz to over 500MHz, with a measuring range from +20dBm down to -60dBm.

The new little Digital RF Power Meter module we're looking at in this article is quite similar to our 2008 design, at least in terms of its functionality.

For example, it again uses an AD8307 logarithmic amp/detector at the input, and then uses a MCU to process the readings and display them on a 16x2 LCD readout.

But in this case the MCU is an STC 12C5A60S2 rather than a PIC16F88, and the whole circuit is on a single PCB measuring only 59 x 57mm. So it's much more compact than our 2008 design, as you can see from the photos.

The block diagram of Fig.1 shows that it's really quite straightforward in terms of circuitry. The RF input is terminated with close to 50Ω and then fed straight into the AD8307, which converts it into a DC output voltage varying between about 100mV and 2.5V in proportion to the logarithm of the RF input level.

The AD8307's nominal conversion characteristic is shown in Fig.2. It's very close to a straight line between input levels of -75dBm and +18dBm, with a slope of 25mV per dB (decibel).

The Analog Devices data sheet for the AD8307 shows the Logarithmic Conformance as ±0.5dB.

This DC output signal is then fed into one of the ADC (analog-to-digital converter) inputs of the 12C5A60S2 MCU, where it is first digitised with a resolution of 10 bits. The firmware in the MCU then uses this digital value to calculate the equivalent RF input level, which it displays on the LCD readout.

Fig.1 shows that

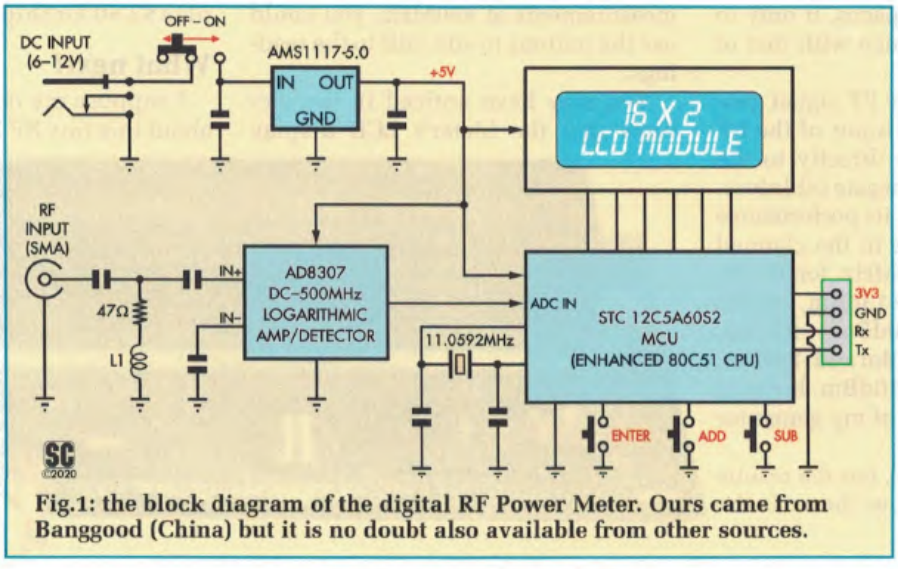
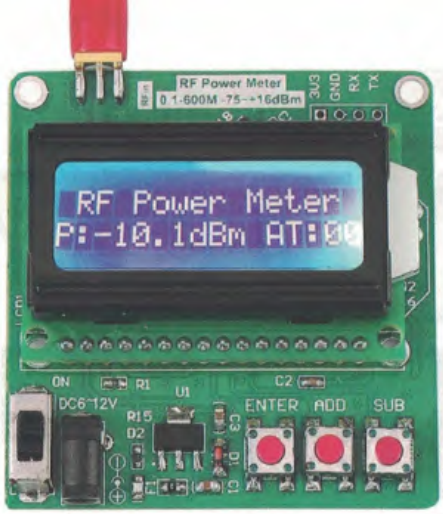


Fig.1: the block diagram of the digital RF Power Meter. Ours came from Banggood (China) but it is no doubt also available from other sources.



(Left): how big is it? This shot of the power meter is same size – 57 x 59mm. It can be powered from 6 to 12V DC.

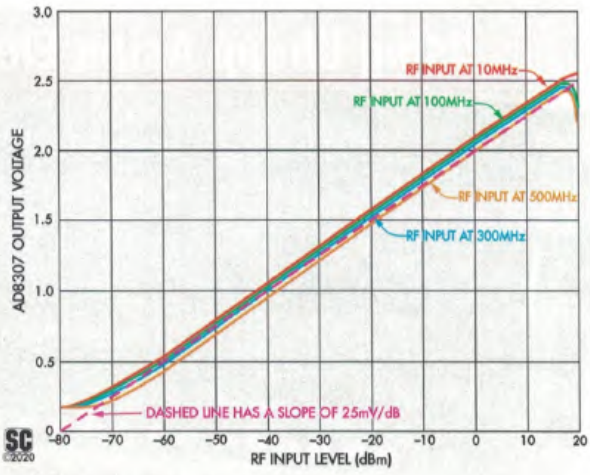

AD8307 OUTPUT VOLTAGE
RF INPUT LEVEL (dBm)
RF INPUT AT 10MHz
RF INPUT AT 100MHz
RF INPUT AT 500MHz
RF INPUT AT 300MHz
DASHED LINE HAS A SLOPE OF 25mV/dB
SC ©2020

Fig.2 (right): the nominal conversion characteristic of the AD8307 logarithmic converter. It's very close to a straight line between -75dBm and +18dBm, with a slope of 25mV/dB.

the module is designed to accept a DC input of between 6V and 12V, and uses an AMS1117-5.0 regulator to provide the rest of the module with a regulated 5.0V supply. Incidentally there's also a reverse-polarity protection diode across the input of the regulator, to 'take the fall' and protect the rest of the components in the event of the power supply being connected with reversed polarity.

The current drain of the module is less than 45mA (including the current drawn by the LCD backlighting).

Note that the MCU is provided with an 11.0592MHz crystal for its master clock. It also has three small pushbutton switches connected to three of its I/O pins, with the switches labelled ENTER, ADD and SUB. These allow you to move the reference level up or down in increments of 1dB, to correct for any known variations in the meter's log-law characteristic at a particular frequency. More about this a little later.

Checking it out

I was interested in putting this little meter through its paces, if only to compare its performance with that of our 2008 project.

So I powered up my RF signal generator, connected the input of the RF Power Meter module directly to the generator's output (to negate cable losses) and began plotting its performance at various frequencies in the claimed range of 100kHz - 600MHz, for 10 different power levels: +13dBm, 0dBm, -10dBm, -20dBm, -30dBm, -40dBm, -50dBm, -60dBm, -70dBm and -75dBm.

(I couldn't test at +16dBm, because the maximum output of my generator is +13dBm.)

It took quite a while, but the results were quite impressive, as shown in the curves of Fig.3.

For the upper seven power levels, the indicated power levels are within the ±0.5dB tolerance bands (shown in yellow), for frequencies between 500kHz and 300MHz – and in many cases between 200kHz and 300MHz.

The indications do fall off above 300MHz, though, and are often about 4dB low at 500MHz and about 7-8dB low at 600MHz.

They also fall off below 200kHz (this could probably be remedied by increasing the value of the AD8307's input coupling capacitors).

At the three lowest power levels (-60dBm, -70dBm and -75dBm) the low-end performance falls away earlier.

But overall, the new RF Power Meter's performance over the frequency range 500kHz – 300MHz compared very well with that of our 2008 project.

And if you want to use it to make measurements at frequencies above 300MHz, you could do so by making use of those ENTER/ADD/SUB buttons to correct the readings.

For example if you want to make measurements at 450MHz, you could use the buttons to add 3dB to the readings.

You may have noticed in the pictures that the Meter's LCD display has an indication at the RH end of the second line, showing any correction figure that may be active for current readings.

For example if you don't enter any correction figure, it will display 'AT:00' after the power reading. This is the default figure, by the way. But if you use the buttons to add say 20dB to the readings to allow for a 20dB attenuator you have connected to the input, it will display 'AT:20'.

So the bottom line is that the performance of this tiny little RF Power Meter compares quite well with that of our 2008 project.

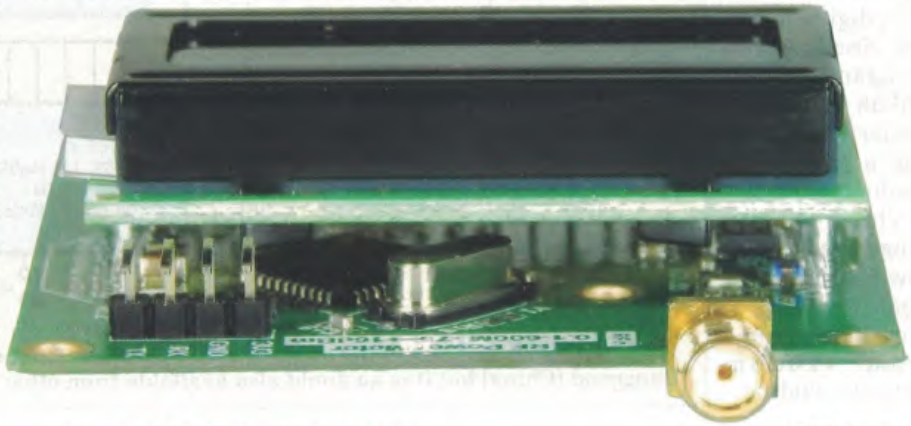
Radio amateurs, hobbyists and service technicians should therefore find it a handy addition to their test instruments – especially considering its low price.

Before closing I should note that you will find this RF Power Meter module on the Banggood website, (**www.banggood.com**). ID no. is 1221705.

At the exchange rate in early June 2020, it was priced at about AU$40.50 plus $3.50 for shipping via Air Parcel.

What next?

I suppose my only real reservation about this tiny RF Power meter is that



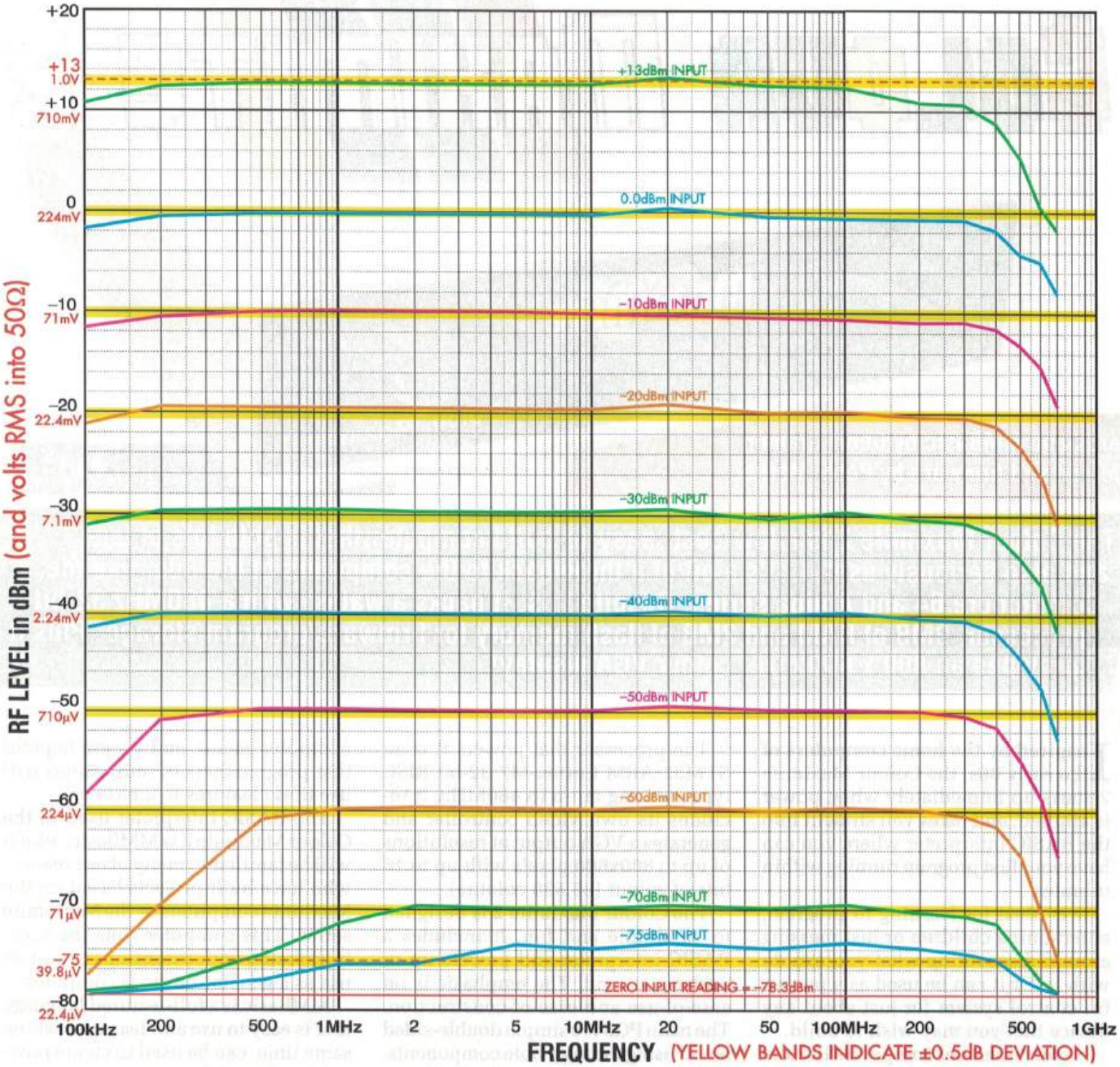
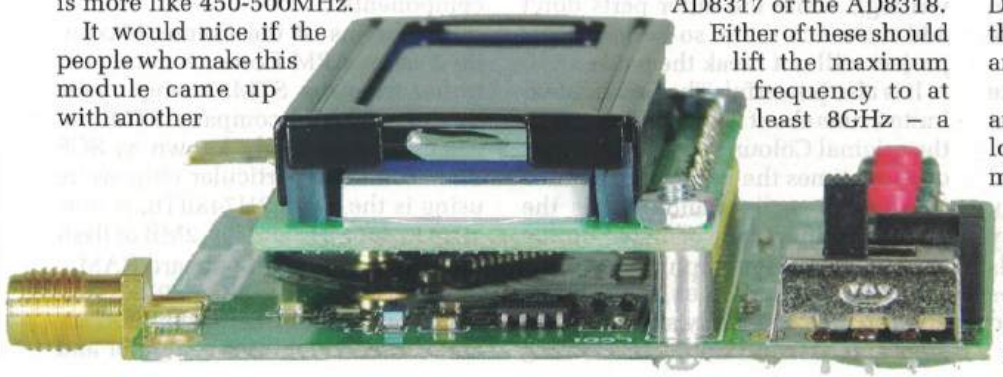


Fig.3: the measured performance of the RF Power Meter we reviewed, at 10 different input power levels and at frequencies between 100kHz and 700MHz. At most power levels the performance is very good between about 500kHz and 300MHz.

even though it's listed as "600MHz", realistically its maximum frequency is more like 450-500MHz.

It would nice if the people who make this module came up with another version using one of the AD8307's more agile sister chips, like the AD8317 or the AD8318. Either of these should lift the maximum frequency to at least 8GHz – a very useful extension.



You may recall that I reviewed an RF Detector module using the AD8318 in the March 2018 issue of SILICON CHIP, and found it an impressive performer.

This chip could be used to produce an RF Power Meter like the one we've looked at in this article, but with a much wider frequency range.

It would need some changes to the MCU's firmware, since the output voltage of both the AD8317 and the AD8318 has a negative slope, compared with the positive slope with the AD8307 (as shown in Fig.2). SC

Colour Maximite 2

Words and MMBasic by Geoff Graham
Design and firmware by Peter Mather

Part 1

The Colour Maximite 2 is a low-cost, easy-to-build computer that is both lots of fun and also seriously useful. It's a bit of a throwback to the computers of the 80s, like the Commodore 64 and Amiga series. Despite this, it packs a wallop with a 480MHz 32-bit processor, 9MB of RAM and 2MB of flash memory for firmware/program storage. Plus it provides an 800 x 600 pixel colour VGA display!

Inspired by the home computers of the early 80s, the Colour Maximite 2 starts up immediately when power is applied, and takes you straight into the BASIC interpreter where you can have your first program running within minutes.

It is ideal for learning to program, entertaining children or just messing around discovering what you can do with it. Or it can be used as a powerful control system for just about any device that you may wish to build.

If you remember computers like the Tandy TRS-80, Commodore 64 or Apple II, you will be right at home with this little beauty. The difference is that the Colour Maximite 2 is about a hundred times faster, has over 100 times as much memory, with higher resolution graphics – and despite all this, costs a fraction of their price!

You may remember the Maximite and Colour Maximite computers that we published in March-May 2011 (siliconchip.com.au/Series/30) and September-October 2012 (siliconchip.com.au/Series/22) respectively. They were huge hits, with many thousands built. The Colour Maximite 2 follows in that vein but with vastly improved technology.

The processor that powers it is an STM32 ARM Cortex-M7 32-bit RISC type running at up to 480MHz. It includes its own video controller and generates a VGA output at resolutions of up to 800x600 pixels with up to 16 bits of colour (65,536 colours).

The Colour Maximite 2 is designed to be simple and fun. It includes a BASIC interpreter and powers up in under a second. The emphasis is on ease-of-use and ease-of-construction. The main PCB is a simple double-sided board using through-hole components, and the whole thing can be built in a couple of hours.

The complex part, the plug-in CPU module, is pre-assembled and costs just US$30 (about $45 at the time of writing), while the other parts don't add too much more, so building this project will not break the bank.

It is also powerful. The Colour Maximite 2 runs about ten times faster than the original Colour Maximite and has over ten times the program space.

Where it really stands out is the quality of the video generated on the VGA output. The graphics are rock-solid, and with up to 65,536 colours, you can create visually stunning programs. It is well suited to creating computer games, and we are hopeful that programmers of retro games will use these features to amaze us.

The BASIC interpreter used in the Colour Maximite 2 is MMBasic, which will be familiar to many of our readers who have built projects based on the Maximite computers or the Micromite series. This computer runs the same interpreter, with extensions to suit its use as a general-purpose computer.

MMBasic is a full-featured language that is easy to use and learn, but at the same time, can be used to create powerful and useful programs.

Design

Fig.1 shows an assembled Colour Maximite 2 and points out its major components.

The brains of the Colour Maximite 2 is an ARM Cortex-7 microcontroller from the STM32 range made by Europe-based company STMicroelectronics, formerly known as SGS Thomson. The particular chip we're using is the STM32H743IIT6. It runs at up to 480MHz and has 2MB of flash memory and 1MB of onboard RAM.

This CPU has a 32-bit RISC (Reduced Instruction Set Computer) architecture, which uses a simpler and

more consistent set of instruction codes than chips like the x86/x64 series from Intel and AMD.

This chip is at the centre of the Colour Maximite 2 and does almost everything needed to make the computer run. That includes running the BASIC interpreter, holding the BASIC program in memory, communicating with the keyboard, driving the display and controlling the external I/O pins.

The STM32H743IIT6 includes a video processor, which is quite advanced and allows for multiple video planes which can overlap each other, allowing a background to show through. This is managed by the BASIC program, and is particularly useful for making computer games or other complex 2D graphics schemes.

For the mathematically-minded, the CPU includes a hardware double-precision floating-point unit. Double-precision means that the result of any calculations will be very accurate, to 14 significant digits, and the fact that this is implemented in silicon makes it fast.

While the STM32H743IIT6 is a very capable chip, it has one significant disadvantage, which is that it only comes in a large 176-pin surface-mounting package with a tiny 0.2mm gap between its pins. This is challenging to hand-solder and is a barrier to its use by the average home constructor.

Fortunately, Chinese company Waveshare has mounted this chip on a plug-in module with supporting components, and this module costs just US$30 fully assembled. By incorporating this module, we managed to design the Colour Maximite 2 with a simple double-sided 'motherboard' using through-hole components, which the Waveshare module simply plugs into.

Because the STM32 processor contains its own firmware loader/programmer, you do not need any specialised equipment to load the BASIC interpreter into its flash memory and get it up and running. You can do that in a few simple steps using a personal computer running Windows, Linux or macOS.

Another advantage of this plug-in concept is that if in the future, you suspect that you have damaged the CPU, you can test or rectify this by simply swapping out the module.

As well as hosting the STM32 processor, the Waveshare module includes some extra components including a

Features & Specifications

CPU : 32-bit ARM Cortex-M7 at up to 480MHz with 2MB of flash.

RAM: 1MB on-chip plus 8MB off-chip RAM for BASIC variable storage and video pages.

Display type: Colour VGA output with VGA standard timing. Software selectable pixel resolutions: 800 x 600 (default), 640 x 400, 320 x 200, 480 x 432 & 240 x 216.

Display modes: 8-bit (256 colours; default), 12-bit (4096 colours plus 16 levels of transparency) or 16-bit (65,536 colours).

Graphics: seven built-in fonts, user-designed fonts, lines, circles, squares and control over any pixel with any colour.

Gaming: video layers with selectable levels of transparency, multiple video pages with high-speed copying between pages, BLIT (copy a block of video), SPRITE (animated sprites) and support for the Wii Nunchuk.

Image loading: files formatted as BMP, GIF, JPG or PNG can be loaded from the SD card and positioned on the screen, then scaled and rotated.

Audio: stereo audio output can play WAV, FLAC and MP3 files, computer-generated music (MOD format), synthesised speech, synthesised sound effects and precise sinewave tones.

Storage: SD card socket (up to 128GB formatted in FAT16, FAT32 or exFAT) for storing programs and files. Built-in graphical file manager makes it easy to manage files and directories.

BASIC interpreter: full-featured with support for ANSI and Microsoft BASIC constructs, and unlimited user-defined subroutines and functions.

BASIC data types: three (strings, double-precision floating-point and 64-bit integers) with support for long variable names and arrays with up to five dimensions (limited only by the available RAM).

BASIC programs: size up to 516KB (typically 25,000 lines or more) at speeds of greater than 200,000 lines per second. Data RAM is 5470KB (enough for huge arrays).

Code editor: built-in full-screen editor with colour coded text, unlimited line lengths and sophisticated search and replace.

Compatibility mode: run programs written for the original Colour Maximite.

Clock: battery-backed real-time clock and calendar with software trimming.

Keyboard support: USB (US / UK keyboard layout) including support for wireless keyboards with a USB dongle (but not keyboard/mouse combos).

USB interface: for connecting to a personal computer (Windows, Mac or Linux) as a terminal or for file transfer. Firmware upgrades via USB.

I/O: 28 external I/O lines which can be configured as analog inputs, digital inputs/outputs, frequency counters etc. The pin layout is compatible with the Raspberry Pi HATs.

Serial I/O: communications protocols including 2 x serial, 2 x I^2C, 2 x SPI and Dallas 1-wire.

Firmware upgrades: via USB; no special hardware is required.

Powered: from USB 5V drawing less than 300mA.

voltage regulator, a couple of crystals and an 8MB SDRAM chip. We use this RAM to provide a large amount of memory for the BASIC program (over 5MB), and implement multiple video pages for the video processor.

VGA output

A standard 15-pin VGA connector on the back panel provides the video output. On startup, this is set to 800x600 pixels and 256 colours.

These colours can be selected from a palette of over 65 thousand colours, so almost any practical colour combination can be accommodated. This default mode is perfect for editing and running programs, and MMBasic returns to this setting when a running program ends.

BASIC programs can use the MODE command to select a range of other display resolutions, as listed in the specifications panel. The colour depth can be 8-bits, 12-bits or 16-bits (65,536 colours).

As expected, there are trade-offs with the various modes. Generally, the lower resolution modes with lots of colours are useful for graphically-demanding programs that need to update the screen rapidly.

This is because they require less data be manipulated to update the display; this is particularly handy for computer games. But unless you want to write a graphically intensive game, you will probably be happy with the default 800x600 pixel resolution and 256 colours.

Unlike the original Colour Maximite, the VGA signal is generated by a dedicated graphics processor built into the STM32 chip (called the LCD-TFT display controller). This generates precise VGA signal timings and results in a steady image with very clear characters on the screen.

The video output is generated from an area of RAM (the graphics memory) that is repeatedly sent to the VGA monitor by the display controller, with each pixel represented by one or two bytes in the graphics memory. When MMBasic draws a graphic image, it just sets these bytes to correspond to the colour of the pixels to be displayed – the hardware handles everything else.

This means that the Colour Maximite 2 is always in graphics mode. To display text, the firmware converts each character to its graphic representation by looking up its bitmap and

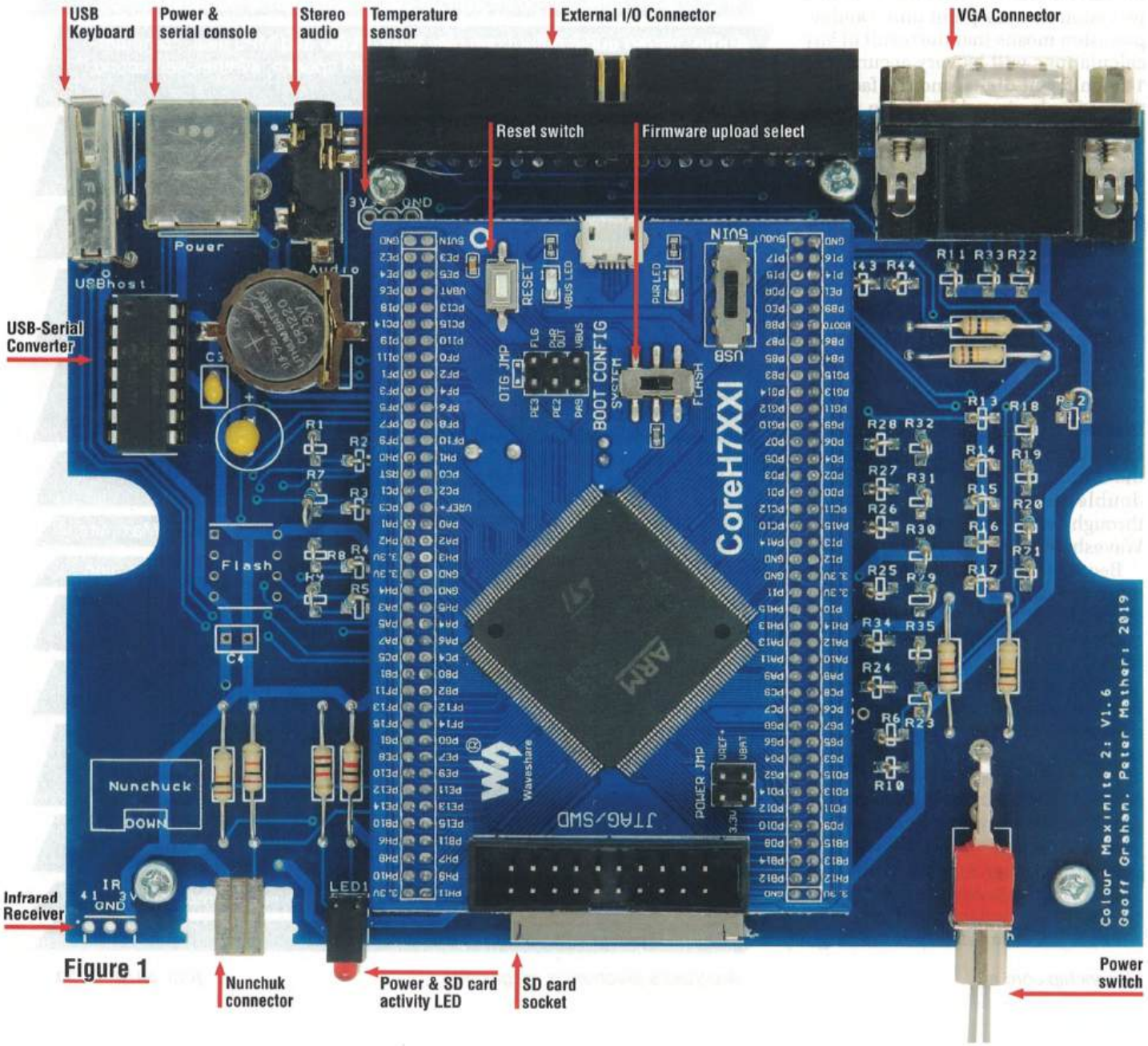


Figure 1

copying this into this graphics memory. This allows for multiple fonts to be implemented and accordingly, the Colour Maximite 2 has seven built-in fonts ranging from small to very large.

Custom fonts can also be embedded in the BASIC program, so programmers have many choices for text display.

For games programmers, the graphics accelerator can be put into a 12-bit colour mode which supports three video layers.

The lowest layer is a solid background colour with the other two layers sitting above this. Images on the upper layers can be specified with various levels of transparency so that (for example) an image on the top layer can be made to move over the lower levels, while allowing some of the lower images to show through the transparent sections of the top image.

This is a powerful feature, and you can expect many games to use this mode.

If an HDMI output is required, an inexpensive VGA-to-HDMI converter can be used. These cost about US$10 (about $15) on eBay and will also encode the audio from the computer. As an example, the Colour Maximite 2 was successfully tested with this device from Banggood (see below right): siliconchip.com.au/link/ab2e

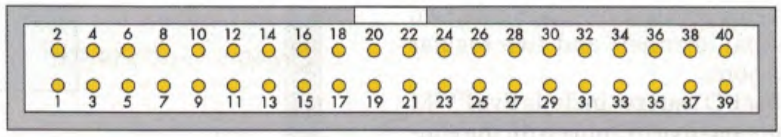
You might be tempted to ask "why not provide HDMI in the first place?" The answer is that the LCD-TFT graphic controller cannot generate it, so we would need to add an expensive and complex chip, which in the end would cost a lot more than a cheap VGA-to-HDMI converter. Plus there is a substantial licensing fee for using the HDMI standard.

I/O capabilities

Also on the back panel is a 40-pin connector which provides 28 digital input/output pins that can be controlled from within the BASIC program, plus several 3.3V, 5.0V and ground pins for powering external circuitry.

The pin layout and the positioning of special functions is compatible with the Raspberry Pi, so you can connect various add-on boards designed for the Raspberry Pi (they are called Pi HATs) and use them with this computer.

The I/O connector's pinout is shown in Fig.2, and it includes a mixture of 28 digital I/O pins, 12 analog pins for measuring voltages, two SPI



PIN	FUNCTION	
1	+3.3V Power	
3	I²C SDA	5V
5	I²C SCL	5V
7	Analog I/O or COUNT 1	
9	Ground	
11	COM2: Rx	5V
13	Analog I/O or COUNT 2	
15	Analog I/O or COUNT 3	
17	+3.3V Power	
19	SPI MOSI	5V
21	SPI MISO	5V
23	SPI CLOCK	5V
25	Ground	
27	I²C2 SDA	5V
29	Analog I/O or PWM-1C	
31	PWM 2B	5V
33	General I/O	5V
35	SPI2 MISO	5V
37	Analog I/O or COM1 DE	
39	Ground	

PIN	FUNCTION	
2	+5.0V Power	
4	+5.0V Power	
6	Ground	
8	Analog I/O or COM1: Tx	
10	Analog I/O or COM1: Rx	
12	Analog I/O or PWM 1A	
14	Ground	
16	Analog I/O or COM2: Tx	
18	FAST COUNT	5V
20	Ground	
22	Analog I/O or PWM 1B	
24	Analog I/O or COUNT 4	
26	Analog I/O	
28	I²C2 SCK	5V
30	Ground	
32	General I/O	5V
34	Ground	
36	PWM 2A	5V
38	SPI2 MOSI	5V
40	SPI2 CLOCK	5V

Fig.2: the I/O socket on the rear panel is compatible with the Raspberry Pi, so you can connect various add-on boards designed for the Pi (called Pi HATs). It includes 28 input/output pins that can be controlled from within the BASIC program plus several 3.3V, 5V and ground pins for powering external circuitry.

An HDMI output can be provided by inexpensive VGA to HDMI converters like this. They cost about $15 on eBay. ***Photo from banggood.com***

The Nunchuk is a controller developed for the Nintendo Wii. The Colour Maximite 2 has full support for it, and many games written for the Colour Maximite 2 use it. ***Source: Wikimedia, Author Tsukihito***

serial communications channels, two I²C serial channels and two regular serial ports.

Other I/O features include five PWM outputs and five I/O pins with the ability to measure frequency, period or general timing (one of these can run up to 40MHz – useful as a general-purpose frequency meter). 16 of the pins are 5V-tolerant, so they can be used to interface with 5V circuits.

Sound generation

Near the I/O connector on the rear panel is the audio output, a 3.5mm stereo phono socket suitable for feeding into an amplifier or amplified speakers. The STM32 chip includes its own twin DACs (digital-to-analog converters), and these generate stereo audio while not affecting the performance of the CPU.

Under the control of the BASIC program, you can play music or sound effects stored in a variety of formats (WAV, FLAC and MP3). The Colour Maximite 2 can also play computer-generated music in the MOD format, which was popular with computers in the 80s and 90s.

Other features include the ability to output computer-generated speech (stored in the TTS format) and the ability to generate sound effects composed of a mixture of sine, triangle and noise waveforms.

Finally (as if that was not enough), the Colour Maximite 2 can generate audio sine waves with a very accurate frequency, and this can be used for making a simple beep or testing amplifiers, speakers etc.

Power, console & keyboard

Next to the audio connector on the back panel is a USB Type-B connector for power and access to the serial console over USB.

The Colour Maximite 2 is powered from 5V at about 300mA, well within the capabilities of most computer USB ports and USB chargers. However, some older laptops and cheap chargers can cause trouble, so be prepared to try a different power source if you experience random restarts, hangs or video or keyboard problems.

This serial-over-USB function allows a personal computer to access the Colour Maximite 2's console. Everything that could be done with a keyboard/monitor (except graphics) can also be done over this interface.

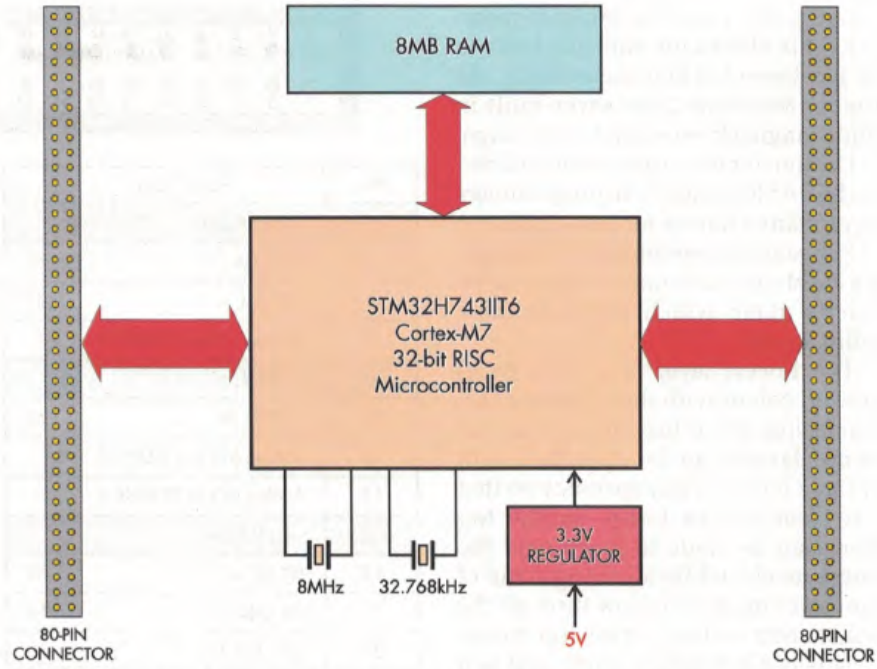


Fig.3: this block diagram is of the Waveshare CoreH743I plug-in CPU board, which provides the Colour Maximite 2 with its computing power. It includes an STM32 ARM Cortex-7 microcontroller, a 3.3V regulator, two crystals, an 8MB SDRAM chip and some components supporting the USB interface.

This means that you can run the Colour Maximite 2 without an attached keyboard and monitor if you wish.

The main benefit of this interface is that it is easy to transfer programs and data between the two computers. This allows you to use the bigger computer to edit and manage the program, while testing it on the Colour Maximite 2. But with an attached keyboard and monitor, the Colour Maximite 2 is a capable computer in its own right, so you can use either arrangement as you fancy.

Next to the power connector is a Type-A USB connector for a USB keyboard. The original Colour Maximite used a PS/2 connector for this, but PS/2 keyboards are getting hard to find, so being able to use a USB keyboard is a welcome improvement.

This feature supports most keyboards, including those with a wireless dongle, so you have plenty of choices. One restriction is that you cannot use a USB hub on this port and as a consequence, keyboards with a built-in mouse will not work.

Nunchuk connector

On the front panel of the Colour Maximite 2 there is a connector for the Nunchuk games controller. This was created by Nintendo for its popular Wii gaming console, and has been cloned by many Chinese manufactures, so it is widely available and quite cheap (under $10 locally).

The Nunchuk is well-equipped with a four-position joystick, two pushbutton switches and an accelerometer. You can query the state of the joystick and the switches from BASIC, and get the current outputs of the accelerometer.

Usually, only one Nunchuk is required, but MMBasic supports up to three Nunchuks (the other two connect via the rear I/O connector), so you can have multiple players at the same time.

Many games written for the Colour Maximite 2 will use the Nunchuk to control gameplay.

Also while not supported out-of-the-box, the Wii Classic Controller uses the same connector and communicates over I²C. So it is possible to make one work with the Maximite, if you wanted a more 'standard' controller. Check out WiiBrew for the data format for Classic Controller's data format: siliconchip.com.au/link/ab2w

SD card

Also on the front panel is a slot for a full-size SD card. The Colour Maximite 2 supports cards up to 128GB, formatted as FAT16, FAT32 or exFAT. These formats are fully compatible with Windows, Linux and Mac com-

puters so you can pop the card out and plug it into your personal computer to transfer programs and data.

Because BASIC programs are generally quite small, you don't need a large SD card. 8GB cards are very cheap and commonly available. You can also use a micro SD card in a micro SD-to-SD card adaptor (often supplied with the card).

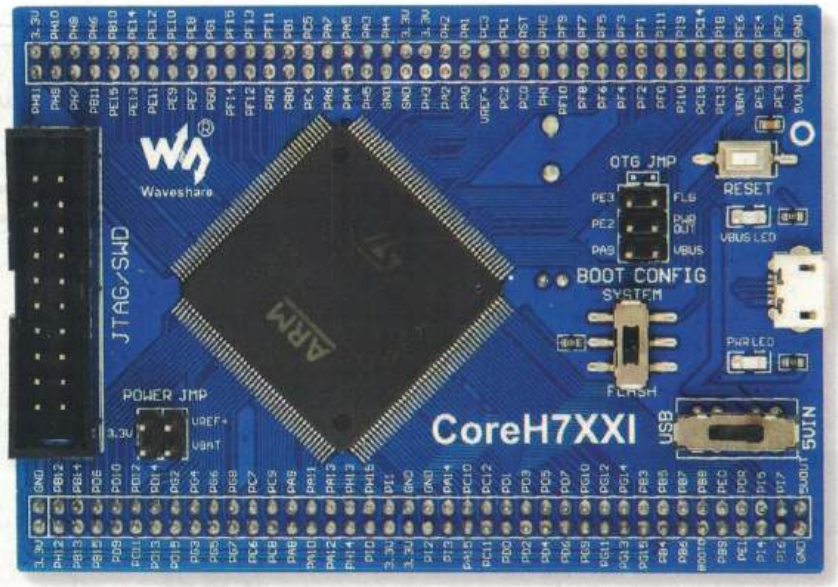
The Colour Maximite 2 relies quite heavily on the SD card. For example, when you edit a program, it resides on the SD card, and you will also run the program from there. This is different from the original Colour Maximite where you did not need an SD card, as programs were edited and run from the computer's random access memory (RAM).

The Colour Maximite 2 does not do this because when a program is loaded, the firmware performs a lot of preprocessing to optimise the program for speed. This includes inserting any include files, stripping out comments and spaces and other speed-orientated changes.

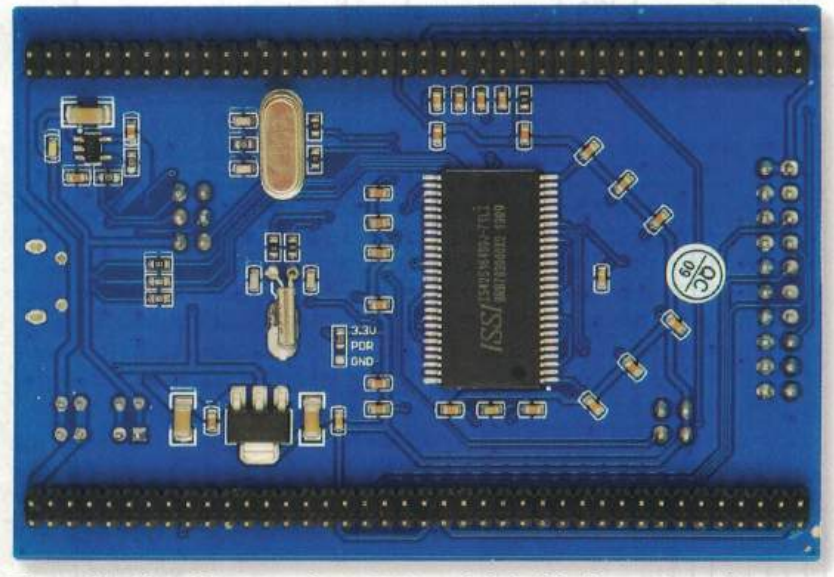
As a result, the program stored in the main chip is not easy for a human to read, which is why you only ever edit or list the SD card copy of the program.

As well as the much-improved speed, with the Colour Maximite 2, this means that program comments do not use up space in the program memory. So you can be as lavish with them as you wish.

The compressed program is stored in flash memory, but that is transparent to the user. However, this means that after the program has started running, you can swap out the SD card with another containing the data required by the program. If the computer restarts (perhaps due to a power failure), the program can automatically restart, regardless of what has happened with the SD card.



The top side of the CPU module holds the STM32 ARM Cortex-7 STM32H743IIT6 CPU, which is in a 176-pin SMD package. There is a tiny 0.2mm gap between its pins, which is why we used this Waveshare module rather than asking constructors to solder it.



The underside of the Waveshare CPU module holds the 3.3V regulator, two crystals (8MHz and 32.768kHz), 8MB SDRAM chip and some components supporting the USB interface. The SDRAM provides a large amount of RAM for the BASIC program (in addition to the 1MB within the ARM chip) and allows for multiple video pages for the video processor.

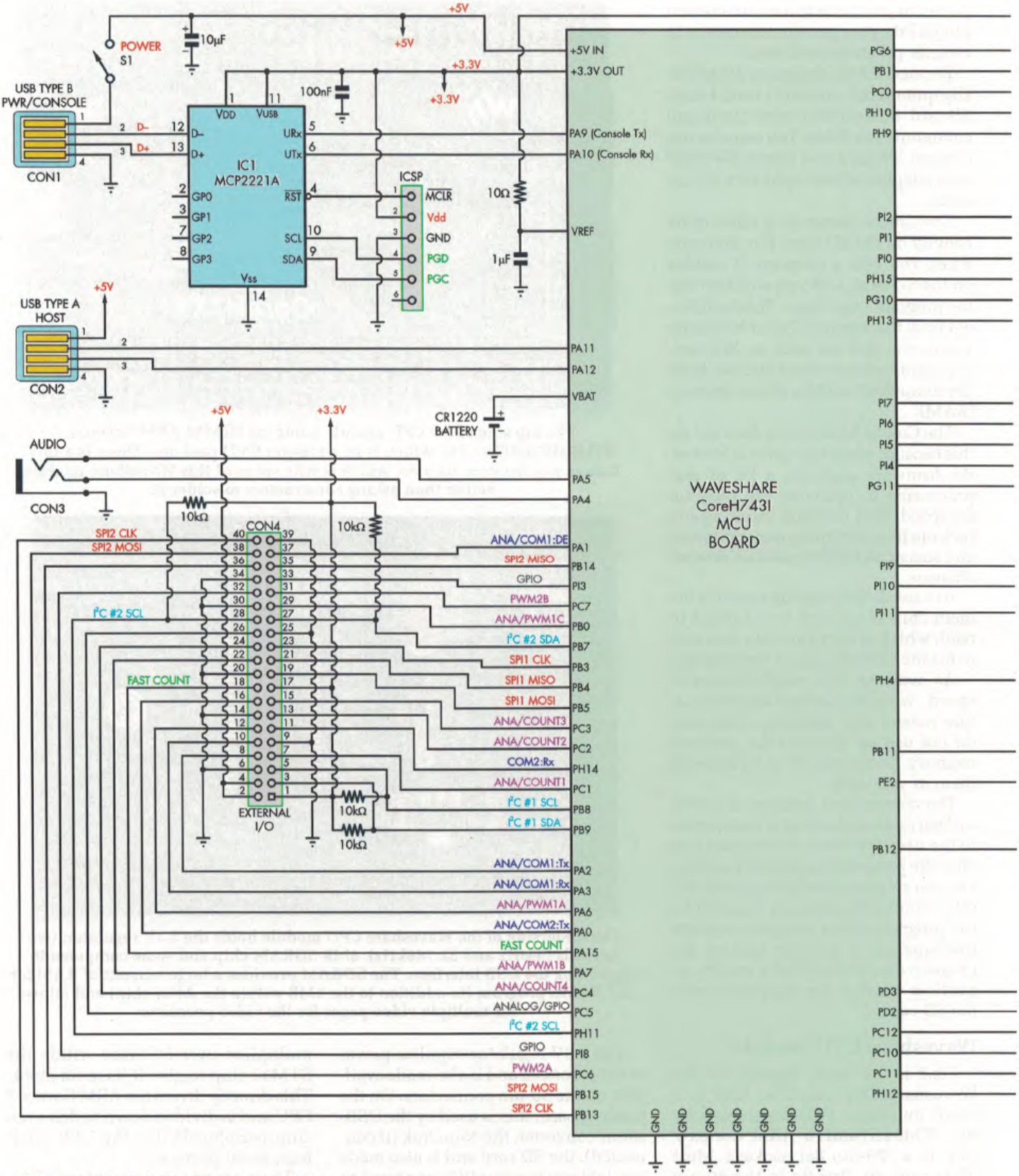
Waveshare CPU module

Fig.3 is the block diagram for the Waveshare CPU module. This is a small four-layer PCB dominated by the STM32H743IIT6 ARM Cortex-7 CPU in a 176-pin flat package. Most of its pins go directly to the 80-pin connectors on either edge of the module. The only other significant components are the 3.3V regulator, two crystals, an 8MB SDRAM chip and some components supporting the USB interface.

The 3.3V regulator supplies power to the processor and is also made available on the 80-pin connectors. On the motherboard, this is used by the USB-serial converter, the Nunchuk (if connected), the SD card and is also made available on the rear I/O connector, to power external circuits. Current draw should be limited to 100mA to prevent the regulator from entering thermal shutdown.

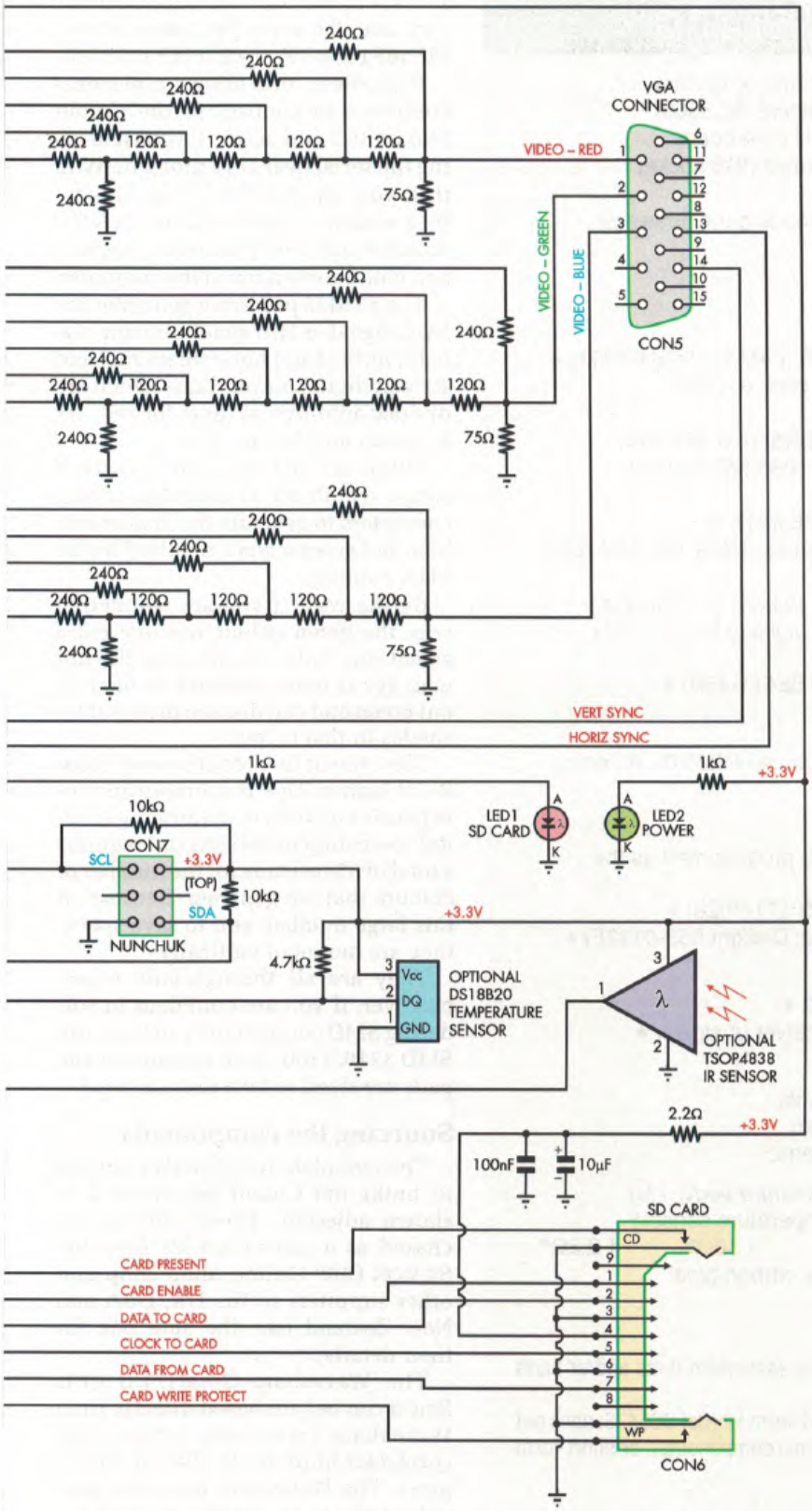
The two crystals on the CPU module are 8MHz and 32768Hz. The 8MHz is multiplied over 50 times within the STM32 chip to give it its main clock. This directly drives the ARM Cortex-7 CPU and is divided down to drive on-chip peripherals like the USB interface, serial ports, etc.

There are two versions of the STM-32H743IIT6. The older one called Rev Y runs at 400MHz, while the newer one is Rev V which runs at 480MHz. Other than this, both versions work identically. The version letter is engraved on the IC, but you can also



SC ©2020 COLOUR MAXIMITE 2

Fig.4: this is the full circuit of the Colour Maximite 2 'motherboard'. It holds the various connectors, the USB-Serial converter and the resistor ladders for the VGA analog output. Most devices such as the Nunchuk, SD card, etc connect directly to the STM32 processor via the two 80-pin connectors.



tell by using the command PRINT MM.INFO(CPUSPEED) which will tell you the speed of the chip.

As there may be some old stock in circulation, you could get either version when you order a Waveshare board. Regardless, both versions of this chip are crazy fast so you will not notice this small difference.

The 32768Hz crystal (sometimes written as 32.768kHz) is used by the real-time clock built into the STM32 processor. A battery on the motherboard powers this clock. So it keeps the time and date, even when the power is off.

You can easily retrieve this time/date for use in your program. The firmware also uses this data to timestamp files on the SD card so that you can tell when they were created or modified.

Like the CPU, the 8MB RAM chip comes pre-mounted on the Waveshare module. The STM32 CPU maps this RAM into its address space, so MMBasic can use it in a similar way to the 1MB of built-in RAM.

MMBasic uses this memory for a variety of jobs, including providing multiple video pages for assembling video images, as a buffer for use when editing a program and as general memory for the BASIC program.

The CoreH743I CPU module has two connectors on the top of the PCB. The first is for a 20-pin ribbon connector which is used for an external JTAG programmer/debugger.

The second is a USB connector, which is not used in this design, as the USB signals from the STM32 processor are routed to the motherboard and then to the USB keyboard socket on the back panel.

Main circuit

The motherboard circuit diagram is shown in Fig.4. It essentially holds the various connectors (VGA, I/O etc), the USB-serial converter, the resistor ladders for the VGA analog signals and little else. Most devices such as the Nunchuk, SD card etc connect directly to the STM32 processor via the two 80-pin connectors.

The backup battery is a CR1220 coin cell which, as described above, keeps the STM32's real-time clock running while the power is off. It also keeps a bank of 4KB RAM alive. This battery needs to be in place, as the 4KB RAM is used to store configuration data and options; if the battery is missing, these will be reset to their defaults when power is removed. That's very annoying, to say the least.

The only other component of significance is the USB-to-serial converter. This is a 14-pin DIP chip and can be either the Microchip MCP2221A USB bridge or our own Microbridge (May 2017: siliconchip.com.au/Article/10648).

Note that instead of the PIC16F1455-

Parts List – Colour Maximite 2

1 double-sided blue PCB coded 07107201, 128mm x 107mm
1 pair of front and rear panels to suit case (optional, SC5500)
1 Waveshare CoreH743I STM32H743IIT6 MCU core board
1 USB 5V power supply or computer with powered USB socket
1 USB Type-A to Type-B cable (for power)
1 USB Type-A to Type-A or micro-B cable (for loading the firmware)
1 USB Type-B right-angle PCB socket (CON1; Amphenol FC1 61729-0010BLF) ♦
1 USB Type-A right-angle PCB socket (CON2; Amphenol FCI 73725-0110BLF) ♦
1 3.5mm stereo jack socket (CON3; Switchcraft 35RASMT4BHNTRX) ♦
1 40-way DIL right-angle box header, 2.54mm pitch (CON4; Hirose HIF3F-40PA-2.54DS{71}) ♦
1 15-pin right-angle HD D-sub PCB socket (CON5) [RS 481-443, element14 2401183/2857990, Digi-key AE11036-ND, Mouser 523-7HDE15SDH4RHNVGA]
1 SD card socket (CON6; Hirose DM1AA-SF-PEJ{21}) ♦
2 80-way DIL sockets, 2mm pitch (CON7-8; Samtec MMS-140-01-L-DV) [eBay 292145372983]
1 right-angle vertical PCB-mount SPDT toggle switch (S1) [Altronics S1320, RS 734-7107, element14 9473297, Digi-key EG2364-ND, Mouser 34ASP27T7M2QT]
1 button cell holder for CR1220 (BAT1; Harwin S8411-45R) ♦
1 CR1220 lithium button cell (BAT1)
1 14-pin DIL IC socket (for IC1)
1 plastic instrument case, 140 x 110 x 35mm [Jaycar HB5970, Altronics H0472, element14 1526699]

Semiconductors
1 PIC16F1455-I/P 8-bit microcontroller, DIP-14, programmed as the Microbridge (IC1) OR
1 MCP2221A-I/P USB bridge, DIP-14 (IC1) (RS 171-7828) ♦
1 3mm dual green/red LED assembly (LEDs1-2; Dialight 553-0112F) ♦

Optional components
1 Dallas DS18B20+ temperature sensor, TO-92 ♦
1 Vishay TSOP4838 38kHz infrared remote receiver or similar ♦

Capacitors
2 10µF 16V X7R through-hole multi-layer ceramic
1 1µF 50V X7R through-hole multi-layer ceramic
2 100nF 50V X7R through-hole multi-layer ceramic

Resistors *(all metal film, 0.125W or 0.25W miniature body, 1%)*
6 10kΩ■ 1 4.7kΩ■ (for optional DS18B20 temperature sensor)
2 1kΩ■ 19 240Ω 13 120Ω 3 75Ω 1 10Ω■ 1 2.2Ω■
■ *can be larger body 0.5/0.6W metal film or 5% carbon type*

Where to get a kit

These suppliers are planning to either offer kits, fully assembled units and/or parts (PCB etc) for the Colour Maximite 2.

- Silicon Chip Online Shop: PCB (Cat SC5461); short-form kit (Cat SC5478; does not include the CPU module, case, power supply or optional components); or short-form kit **with** CPU module (Cat SC5508)
- Rictech in New Zealand (www.rictech.nz)
- Micromite Org in the UK (https://micromite.org/)
- CircuitGizmos in the USA (http://circuitgizmos.com/Color-Maximite-2-p192570471)

If you want to source your own parts, you can download the construction kit from the author's website at http://geoffg.net/maximite.html This includes the Gerber design files for the motherboard PCB so that you can get it made by a PCB fabrication house.

♦ *available from RS Components, element14, Digi-Key and Mouser.*

I/P specified for the Microbridge, you can also use a PIC16LF1455-I/P, PIC16F1454-I/P or PIC16LF1454-I/P.

Regardless, this allows a personal computer to connect to the Colour Maximite 2 and access its console using the serial over USB protocol. With this, you can use the Colour Maximite 2 without a keyboard and/or VGA monitor, and easily transfer programs and data between it and the computer.

The STM32 processor generates the VGA signal as two synchronising signals (vertical and horizontal sync) and sixteen digital output lines which are divided into five outputs for red, six for green and five for blue.

These are fed into three resistor arrays which act as digital-to-analog converters to generate the analog red, blue and green signals required by the VGA monitor.

By the way, if you are wondering why the green colour has one extra signal line (bit), it is because the human eye is more sensitive to the colour green and can discern more subtle shades in that colour.

The type of this resistor array is an R–2R ladder. This is a simple and inexpensive method of performing a digital-to-analog conversion and requires a total of 35 resistors for the number of colours that we generate. Because of this large number, and to save space, they are mounted vertically.

They are all through-hole types; however, if you are confident in soldering SMD components, you can use SMD 3216/1206-sized resistors as the pads are sized to take these as well.

Sourcing the components

The complete list of parts required to build the Colour Maximite 2 is shown adjacent. These can be purchased as a short-form kit from the Silicon Chip Online Shop shop and other suppliers in the UK, USA and New Zealand (see the side box for their details).

The Waveshare CoreH743I CPU Board can be purchased directly from Waveshare (www.waveshare.com/coreh743i.htm) or via eBay or AliExpress. The Waveshare page also provides links to the module's specifications and the circuit diagram.

The two 80-pin sockets used to connect the Waveshare board have a pin spacing of 2mm rather than the more usual 2.54mm (0.1-inch). They can be purchased from the usual sup-

pliers (Mouser, RS Components etc) but tend to be expensive. We found a much cheaper source on eBay, and they were of good quality and worked perfectly (search eBay for "2mm 2x40 Pin Female PCB Header").

You need to be careful with the vertical Type-A USB connector used for the keyboard. There are two variants that look identical but have their PCB pins reversed.

To avoid damaging your keyboard or the Waveshare board, you need to make sure that you have purchased the correct type which is manufactured by Amphenol FCI with their part number 73725-0110BLF.

Mouser sells this (Cat 649-73725-0110BLF) as does RS Components (771-0048).

To make fitting the resistors easy and avoid them getting in the way of the Waveshare board, it is best if they are 0.25W metal film resistors (these are much smaller than carbon resistors). The tolerance is not critical in this application, but most metal film resistors are 1% tolerance anyway.

Finally, we have specified a vertically-mounted LED module for the power and SD card activity LEDs. Using this module makes it easy to get the correct alignment with the matching holes in the front panel, but you can use discrete 3mm LEDs. If you do this, you will have to bend their leads and jiggle them around to get the correct alignment.

Advanced features

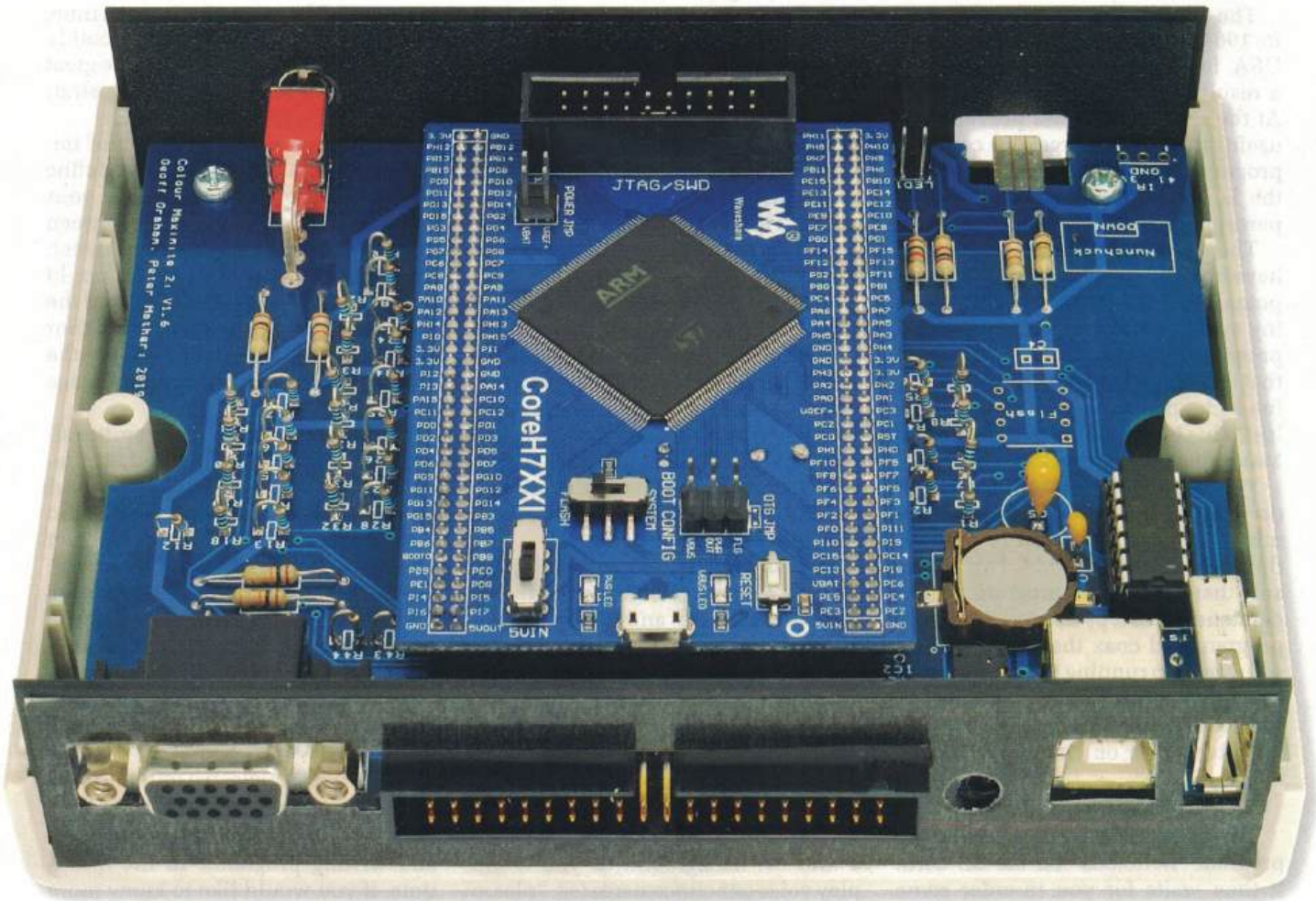
A very useful built-in feature in the Colour Maximite 2's firmware is a graphical file manager that lets you use the arrow keys to move around a list of directories and files.

These can then be deleted, renamed, run, edited etc all from within the file manager. This makes it easy to manage even a large number of files on the SD card.

Within your BASIC program, you have full access to the SD card so you can change directories and create, delete and rename both files and directories. Up to ten files can be simultaneously open for reading, writing and random access. This is similar to the disk access that you have on a personal computer, so you can think of the SD card as the Colour Maximite's "hard drive".

The motherboard includes a coin battery which is used to keep the clock inside the STM32 processor alive. So the Colour Maximite 2 always knows the correct time and date, which are used to timestamp files on the SD card. The time and date are also available to the BASIC program.

The motherboard also has provision (on the front) for an infrared receiver, so that you can use a universal IR remote control to send instructions to your BASIC program. Finally, on the rear panel, there is provision for a



The assembled Colour Maximite 2, with its lid removed. The motherboard shown here is an early prototype – the final PCB has some small changes. On the rear panel, you can see the VGA connector, the 40-pin I/O connector, audio output socket, the USB Type-B connector for power and serial terminal and finally, the Type-A connector for a USB keyboard.

DS18B20 temperature sensor so you can measure the ambient temperature from within your program.

MMBasic interpreter

While the hardware is important in making the Colour Maximite 2 what it is, the other important part is the firmware and in particular, the MMBasic interpreter.

This is designed to resemble Microsoft BASIC, which was used in many computers of the early 80s. This means that many of the programs of that era can, with a few modifications, run on this computer.

When the Colour Maximite 2 powers up, it immediately loads the BASIC interpreter and presents a command prompt. You are straight away ready to enter a program, or run a program from the SD card. This immediacy and ease-of-use is what made the early computers so much fun and so easy to learn, and the Colour Maximite 2 is the same in this respect.

The BASIC language was created in 1964 at Dartmouth College in the USA for teaching programming. As a result, it is easy to use and learn. At the same time, it has proved to be useful in creating large and complex programs, and this led to it becoming the language of choice for the early personal computers.

These days, personal computers have evolved into something far more potent with their complicated operating systems and even more complex programming languages. However, in that evolution, the ease-of-use and the fun factor of the early computers were lost. This is something that the Colour Maximite 2 brings back.

Typically, the first thing people will do with a new computer or programming language is to get it to produce the phrase "Hello World". This makes sure that the budding programmer understands the steps needed to create a program and coax the computer and software into running it. On the Colour Maximite 2, this just requires the following steps. At the command prompt (ie, after power on), enter:

```
EDIT "hello"
```

This starts the editor and creates the program "hello.bas" on the SD card. It then waits for you to enter some text. Type:

```
PRINT "Hello World"
```

Maximite 2 Graphics Demos

As examples of the graphic capability of the Colour Maximite 2 check these short videos:

https://youtu.be/h5gtEo5zkGo
https://youtu.be/tzUwGCgYMAY
https://youtu.be/JMOrlBthwQc
https://youtu.be/edt647Dy6F8

Then press the F2 key to save the program and immediately run it. You should see the words "Hello World" appear on the screen.

That's it. Within a minute, you have created and run your first program!

If (somehow) you entered this short program incorrectly, the BASIC interpreter will display a message indicating what the problem was. All you need to do is press the F4 key, taking you back to the editor with the cursor positioned on the line that caused the trouble. You can then correct the fault and press F2 to save and instantly re-run the program. It's that easy.

More on programming

A tutorial called "Introduction to Programming with the Colour Maximite 2" is available as a free download (siliconchip.com.au/link/ab30). This will take you through programming in BASIC, controlling the I/O pins and so on. This is recommended reading for anyone starting with the Colour Maximite 2.

However, there are some special features of this computer that are worth talking about now. Firstly, there is the legacy mode for users of the original Colour Maximite. This makes it easy to migrate programs, as it changes the drawing commands such as LINE, CIRCLE and PIXEL to use the original Colour Maximite syntax and accept colours in the range of 0 to 7.

This is not a perfect emulation, as there are other changes to MMBasic between the old and the new, but it makes it much easier to run old programs – especially ones that use graphics.

One new feature is the ability to play audio files through the audio output. These files reside on the SD card and can be encoded as MP3, FLAC or WAV. This means your program can have a musical background or you could play voice announcements (eg, "please close the fridge door") or play sound effects (explosions, etc).

You can also play audio files at the command prompt. If you tell MMBasic to play a directory containing audio files, the firmware will play each, one after the other, in the background and keep doing that while you are using the computer for other tasks (editing, running a program, etc). So you can have music while you work!

Another very handy feature is the ability to load images from the SD card and display them on the VGA output. Images can be encoded as BMP, GIF, JPG or PNG and you can specify exactly where on the screen they should be located.

This feature could be used to create a slide show of your favourite holiday snaps, but its main application is to display a detailed background for your program or load a logo, or a diagram to brighten up your program.

You can also manipulate these images. You can scale them (make them bigger or smaller), rotate them and move them. Because the Colour Maximite 2 is so fast, you can (for example) move an image sideways one pixel at a time, and the image will slide smoothly across the screen. This would be great in a game, or as a method of illustrating some action in a program.

While we are on the subject of image manipulation, you can also define sprites. These are images that your program can move around the screen while leaving the background intact. For example, the background could be a road (loaded as an image) and the sprite could be the image of a car. Your program could move the car over the road while not disturbing the image of the road.

A program can have many sprites simultaneously on display, and MMBasic will keep track of their location and tell your program if there is a collision between any of them as you move them about. The sprites are in PNG format; each pixel can be one of 4096 colours and also have a degree of transparency.

This latter feature will let the background show through, so you can have transparent sprites if you wish.

Next month

In the next article, we will describe the construction (it is easy) and provide some pointers for using MMBasic and writing programs. In the meantime, if you would like to know more about the Colour Maximite 2, you can download the User's Manual from siliconchip.com.au/link/ab2z SC

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JIM ROWE reviews a "Chinese Cheapie" radio

Pocket-sized DAB+/FM Radio with SD card music player

DAB+ Digital Audio Broadcasting

If you've tried to buy a portable DAB+/FM radio locally, you'll know how expensive they can be! This one, that fits in a shirt pocket, won't break the bank and it also has a built-in micro-SD card music player capable of playing both MP3 and WAV files. Other features include a 3.5mm stereo headphone socket and a rechargeable 1000mAh Li-ion battery.

Digital Broadcast Radio, using the DAB+ system, has been available in most of Australia's capital cities for just over 10 years now.

Many people in these cities have one or more DAB+ receivers in their homes and/or offices. And many cars now also come with DAB+ radios as standard (or in some cases, as an extra-cost option).

DAB+ is gradually expanding to larger regional cities as well.

As it is a digital service, DAB+ stations lack the noise and (generally) the interference which can plague AM and FM stations.

In fact there are many areas in capital cities where AM radio reception is virtually impossible due to noise on the band (one street just a few hundred metres from the SILICON CHIP office is [in]famous for this!). Fortunately all AM radio stations are also found on the DAB+ band.

Even more importantly, there are also *many* more DAB+ stations available than in the analog bands, although the sound quality can sometimes be lacking due to the low digital compression bit rates used.

Having said that, if you live in a country town or many of the smaller regional cities, the above will seem a bit academic since you probably won't have access to DAB+ reception yet.

But if you do live in one of our capital cities and have access to DAB+ reception, you may have noticed that until now, there have been very few portable or pocket-sized DAB+ receivers available – especially at affordable prices. Luckily this has now changed for the better, with the little radio we're discussing here.

The radio in question

It comes from China, and it's called the DAB-P9. It is available from online suppliers such as eBay, AliExpress and Banggood for around $40-50 including delivery.

See the following links:

- www.ebay.com.au/i/143470286230
- www.aliexpress.com/i/33051199955.htm
- www.banggood.com/DAB-P9

... or just search the web for "DAB-P9" to find other options.

But wait, there's more! (No, you don't get a free set of steak knives.) As well as having DAB+ and FM reception, it also lets you listen to digital music files (either MP3 or uncompressed WAV files) from a micro-SD (TF) card.

It can handle cards with a capacity of up to 32GB, so a single card can store up to around 40 hours of CD-quality WAV music files, or hundreds of hours of compressed MP3 files.

It's powered by a built-in rechargeable 3.7V/1000mAh lithium-ion battery which can be recharged from any source of regulated 5V DC. It even comes with a 1m USB-A to micro-B USB cable which can connect it to a PC, laptop or standard USB power pack.

Despite its tiny size, it has an LCD screen which, like most of the larger DAB+ receivers, shows both the station name and the 'running data' along the bottom when you are receiving a DAB+ signal. In FM reception mode, it instead displays the station frequency and the time.

It can scan for DAB+ 'stations' and save the settings for 10 of them in its memory. It can also do this in FM reception mode.

It has a built-in speaker, but understandably this is pretty tiny; a mere 23mm in diameter. That makes it OK for holding up to your ear, but not for much else. Luckily though, the DAB-P9 also has a 3.5mm stereo headphone jack, so you can plug in a pair of headphones or earphones of your choice, for much better listening.

User interface

As you can see from the pictures, for such a tiny radio, the DAB-P9 has a surprising number of control buttons.

Features & specifications

- portable DAB+/FM radio with MP3/WAV playback
- pocket-sized (105 x 62 x 20mm)
- weighs 94g including battery
- DAB/DAB+ reception over the 170-240MHz
- FM reception in the 87.5-108MHz band
- small whip antenna extends to 285mm
- accepts micro-SD cards up to 32GB
- plays MP3 & CD-quality WAV files
- built-in 23mm speaker
- 3.5mm stereo headphone jack socket
- internal 3.7V/1000mAh Li-ion rechargeable battery
- charges from USB @ 5V DC, 1A

Despite its relatively tiny size, the DAB-P9 sports an array of user controls, as these front, side and top photos show. The micro SD card slot is on the side with its + and - program selection buttons immediately above.

Under the LCD window there are three 'lozenge' buttons with functions to set the sleep time, call up the settings menu or jump to a preset station.

The settings menu allows you to set the time (either manually or from the DAB+ signals), set the LCD contrast, the backlight on time and the FM tuning mode.

To the right of these buttons are three that are mainly used for tuning and/or station selection, but also for adjusting the settings menu options. The two outer D-shaped buttons are the left and right buttons, while the rounded square button between them is to confirm your selection.

To the right of the LCD there are three more buttons. The round one at the top is the Mode select button (DAB+/FM/SD), while the rounded rectangular buttons below it are for muting and scanning (during setup).

Then along the top of the radio and moving from left to right are the retracting telescopic antenna, the 3.5mm headphone jack, the USB micro-B socket used for recharging the Li-ion battery, the main on/off switch and a button which can be used to lock or unlock all of the radio's other controls.

At the top of the right-hand side of the DAB-P9 are the UP (+) and DOWN (-) volume control buttons, and just below them, the slot for plugging in the micro-SD card.

In addition to the USB charging cable, a six-page User Guide is also supplied. The pages are rather small at 94 x 106mm, but the text is reasonably easy to read and follow.

Trying it out

After unpacking the radio, I used the supplied USB cable to charge its internal Li-ion battery from a standard USB charger. It will also charge from a computer's USB port.

There's a tiny blue LED visible via a 1mm diameter hole just in front of the micro-B charging socket, which glows to indicate when charging is taking place. It stops glowing when the battery is fully charged.

When it went out, I held down the main power button for a few seconds (described as a 'long-press') until the LCD's backlight came on.

It was then quite easy to extend the antenna and get it to scan for DAB+ and FM stations, after which I could listen to a selected station whenever I wished.

Luckily, I'm in a fairly good area for both DAB+ and FM reception, so the reception in both modes turned out to be very good. The sound was great when I plugged in a pair of decent stereo headphones.

Then I decided to try using it as an SD card music player. I plugged in a micro-SD card on which I had saved several MP3 music files. These played very nicely.

Although the DAB-P9 is only claimed to play compressed MP3 music files, I decided to try replacing that card with another one on which I had saved some CD-quality WAV files (ie, uncompressed 16-bit 44.1kHz digital audio).

The results were very impressive, especially using the stereo 'phones. So I'm happy to confirm that as well as playing MP3 files, the DAB-P9 is also able to play uncompressed WAV files.

I can't really find fault with the DAB-P9 DAB+/FM radio-plus-SD card music player. It's basically a pocket-sized digital music system, with just about everything you could ask for in such a system, at a remarkably low cost.

Admittedly, the built-in speaker is quite tiny and 'tinny', but I'd expect most users nowadays would want to listen via a pair of stereo headphones or earphones anyway. SC

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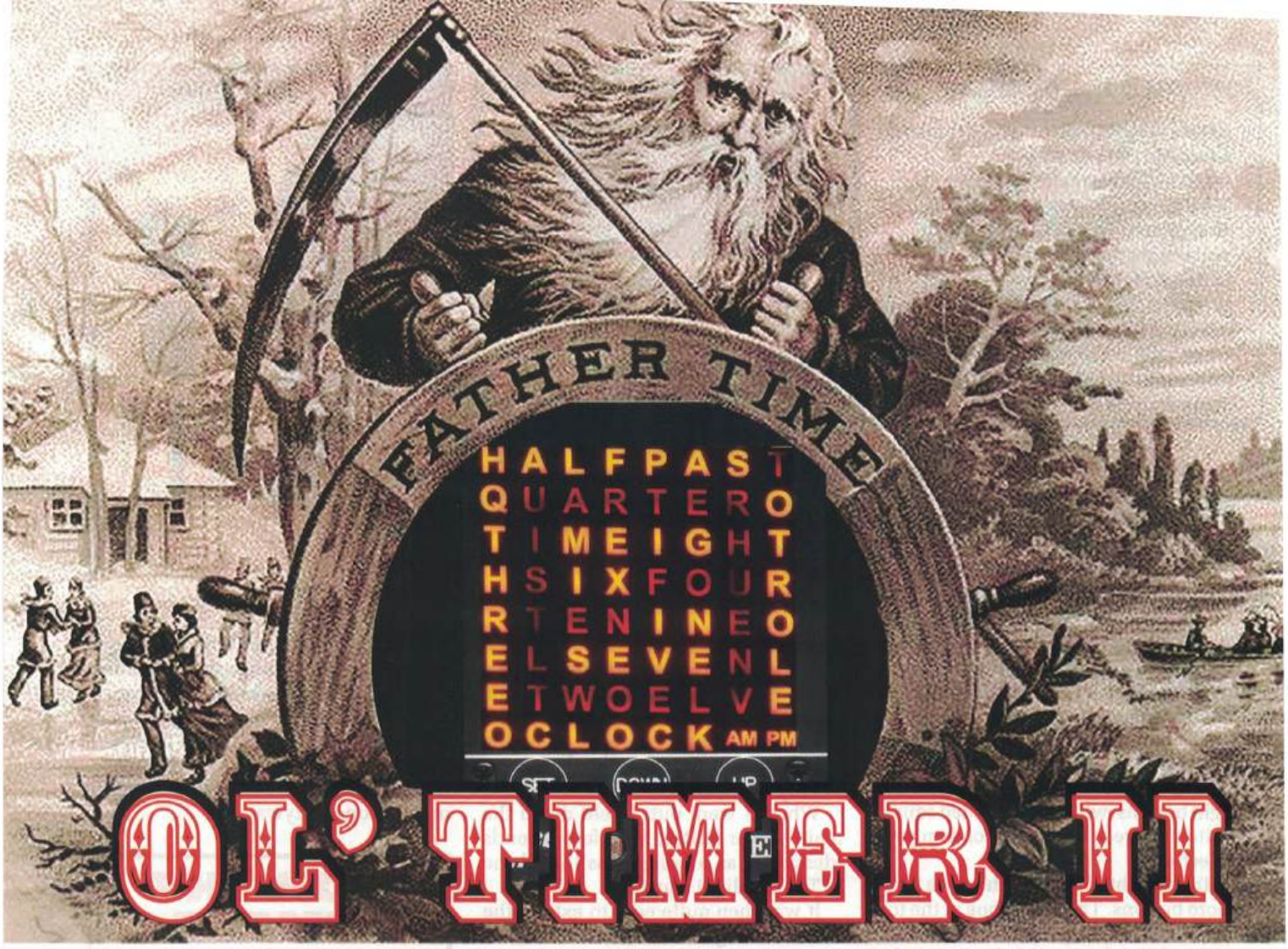


Once upon a time, clocks were not very accurate. Nowadays, the time shown on your mobile phone or computer is probably accurate to a tiny fraction of a second. If you're yearning for a more relaxed attitude to time, this project is for you!

The digital clock in your mobile phone or computer is highly accurate and regularly updated, kept within a fraction of a second of an atomic clock standard via the Internet. But it hasn't always been like that.

When I visited my grandparents as a child, I remember the tall grandfather clock they had in one corner of the house.

Aside from the minor ceremony of its weekly winding, it was practically hidden away and not easy to see, but frequently heard, as it had the type of chimes that would sound off the quarter hours.

On the hour, it would sound off the number of hours; in between, distinct chimes for each quarter-hour. It was easy to tell what the time was to the nearest fifteen minutes.

The Ol' Timer II recalls this more relaxed attitude to time while evoking a modern and stylish appearance.

Inspiration

This project was of course inspired by and named for the (old) Ol' Timer project from November 1994 (siliconchip.com.au/Article/5211). It displayed the time as a combination of words and numbers and used a PIC16C57 microcontroller to control bitmaps on a 40x7 LED matrix.

by Tim Blythman

We now take the PIC microcontrollers for granted but, only a few months prior to the Ol' Timer, an article in the April 1994 issue gave us our first glimpse into their inner workings (siliconchip.com.au/Article/6279).

Back in the day, we didn't need to know the time to the nearest second, and the manner of speaking the time reflected that.

People would say "Quarter to ten" or "five o'clock" instead of "nine-forty-five" or just "five".

The proliferation of digital clocks means that some (many!) younger people can't even read older analog clocks, let alone understand this way of speaking the time!

But the Ol' Timer II displays the time in written words, expressed in this style. The display is only updated every fifteen minutes; this was partly a conscious design decision, and partly because we're limited by what fits on the chosen display.

So if you prefer a relaxed and old-fashioned attitude to time, this clock is for you.

Design

Rather than using a graphical or character LCD, we have combined an 8x8 RGB LED matrix with a cleverly-designed PCB mask, allowing various combinations of letters to be displayed.

It's the sort of thing that could have been rigged up with a matrix of incandescent lamps controlled by clockwork. That is, if we were designing this in the 1920s rather than the 2020s!

So this is how words are displayed on the Ol' Timer II, although the choice of an RGB LED matrix means we aren't limited to illuminating the letters in an 'incandescent yellow' colour.

The RGB matrix is based on 64 WS2812B ICs which each contain red, green and blue LEDs plus a serially-controlled driver chip. We reviewed this type of display in January this year, starting on page 85 (siliconchip.com.au/Article/12228).

Circuit description

Refer to Fig.1, the circuit diagram. The Ol' Timer II is controlled by IC1, a PIC16F1455 8-bit microcontroller.

IC1's RC5 GPIO pin (pin 5) is configured as a digital output, and this drives the serial data input of the LED matrix via a 390Ω resistor and pin header CON3.

The other two pins on the three-pin display header supply 5V power to the 8x8 RGB LED matrix module, MOD1.

Details on how this serial data is used to control the colour and brightness of the 64 LEDs are in the article mentioned above. Suffice it to say that these three lines are sufficient to power and control all the LEDs with individually settable 24-bit RGB colour values, giving 16,777,216 possible colours for each.

IC1's RC4 and RC3 general-purpose I/Os at pins 6 and 7 connect to the I²C serial bus interface of IC2, a DS3231 RTC (real-time clock) IC. Although IC1 has a dedicated I²C interface, its pins are shared with the programming header.

Since I²C is easy to 'bit-bang' with direct port operations, we preferred to do it this way. Thus, IC2 cannot interfere with programming signals and vice versa.

We had sufficient free pins on IC1 to allow us to do this; it also simplifies the PCB layout slightly.

The two I²C lines are pulled up to the 5V supply by a pair of 4.7kΩ resistors, as required by the I²C specification.

IC1's pins 8, 9 and 10 (analog pins AN6, AN5 and AN4 respectively) are connected to circular touchpads on the PCB.

We use the analog to digital converter (ADC) peripheral to sense these pads being touched. A finger on any of the pads alters its capacitance slightly, changing the rate at which it charges or discharges via weak DC currents, enough to be detected by IC1.

These touchpads provide a way to set the unit up even if you don't have a computer with a USB interface handy.

LDR1 has a resistance which changes depending on the light level falling on it. It is connected in series with a 1MΩ resistor across the 5V supply, and a 100nF capacitor smooths the resulting voltage, which is then fed to the AN3 analog input (pin 3) on IC1.

When the LDR is illuminated, its resistance is of the order 100kΩ, and the voltage at AN3 is around 4.5V.

In the dark, the LDR has a resistance around 10MΩ, so the pin 3 voltage is closer to 0.5V. The 100nF capacitor provides a low impedance source for the AN3 analog pin (pin 3), which reads this voltage and calculates a display brightness level based on the ambient light level and user settings.

IC1, IC2 and the LED matrix receive 5V DC power from CON1, a mini-USB socket. IC1 and IC2 each have 100nF local supply bypass capacitors.

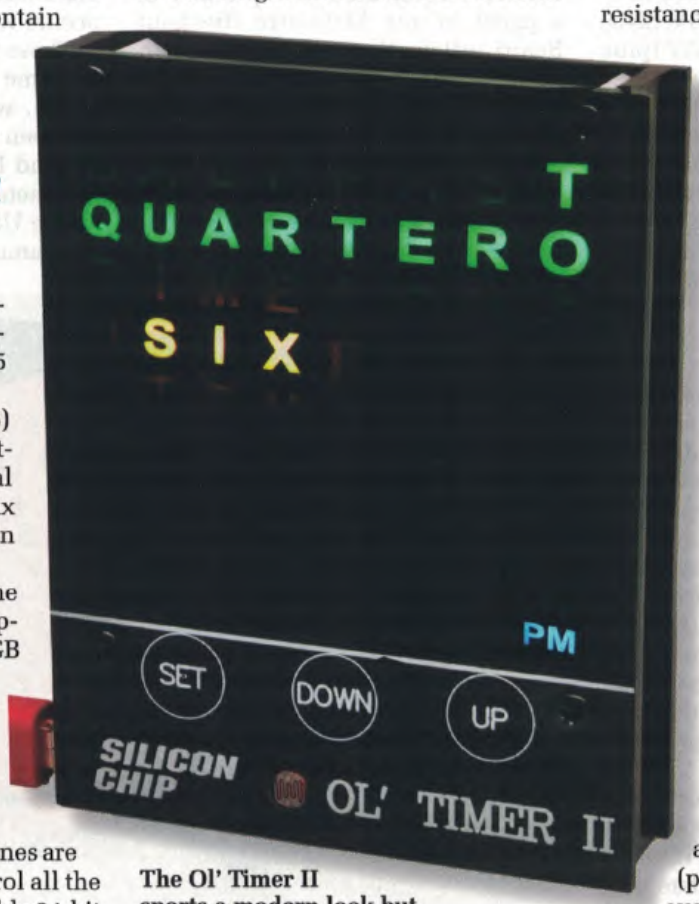
The USB data lines on CON1 are also connected to the dedicated USB D+/D- pins (13 and 12) on IC1, allowing the device to be configured via a computer's USB port.

A 10kΩ resistor provides a pullup for IC1's $\overline{\text{MCLR}}$ pin (pin 4), allowing it to run whenever it is powered.

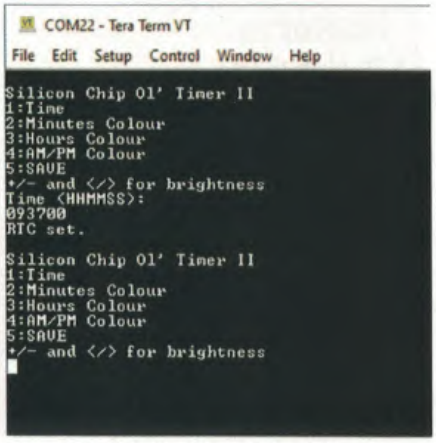
IC2 has support for battery backup power at its pin 14, which is connected to a button cell battery holder. It is

Features

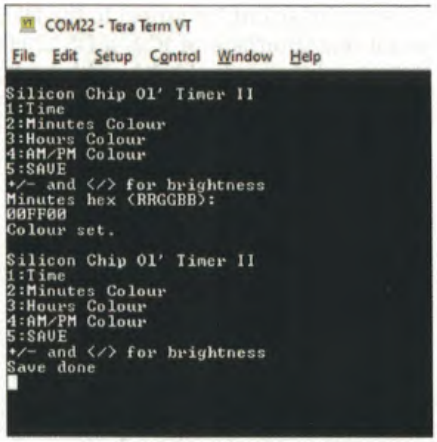
- Displays the time as words
- Uses a DS3231 real-time clock chip for accurate long-term timekeeping
- Compact and stylish
- LED colours are customisable
- USB-powered
- Setup via USB or integrated capacitive touch buttons
- Adjustable brightness with ambient light sensing



The Ol' Timer II sports a modern look but recalls an older way of reading the time. It's powered by 5V from a mini-USB socket, and the display colours are fully customisable.



Screen1: the menu system offered over the USB-serial port is easy to use. Press Esc then 1 to set the time, followed by six digits in 24-hour HHMMSS format.



Screen2: display colours can be set with menu options 2, 3 and 4, in the standard 'web' format of a six-digit hexadecimal colour code in RRGGBB order. The colour shown here (ØØFFØØ) is pure green.

Screen3: pressing Q at any time starts a debugging output display which can be stopped by pressing Esc. The RTC status, digital time and intended LED display are shown and updated every second.

intended to be fitted with a CR2032 type battery, so that the time is kept even when 5V power is removed.

Finally, IC1's in-circuit serial programming (ICSP) pins are wired to CON2 so that IC1 can be programmed after it has been soldered to the board. The required connections are 5V, GND, $\overline{\text{MCLR}}$, ICSPCLK and ICSPDAT (pins 9 and 10). Pins 9 and 10 have 100Ω series resistors to avoid damage to a programmer if it is connected while pins 9 and 10 are being driven.

CON4 is not electrically connected to any part of the circuit, but is used to mechanically secure a corresponding set of pads on MOD1, the LED matrix PCB.

Operation

The general operation of the circuit is typical for microcontroller-based digital circuits and naturally depends heavily on the firmware we have written. IC1 checks the time by querying IC2 over the I^2C bus and then updates the display at CON3 as necessary.

As you might have seen from the article about these modules (and the individual LED chips used in them), the control signal is quite time-sensitive. Thus, we have written this part of the code in assembly language to guarantee the timing.

This includes turning off microcontroller interrupts while the data is being sent to the matrix. We were initially concerned that this might interfere with USB communications (it takes around 2ms to update all the LEDs), but we have not noticed any problems.

IC1's USB peripheral does all the time-critical work independently in hardware, so as long as the software doesn't delay too long, it works fine.

As briefly described above, the three touchpads are probed using the shared capacitance technique. The detail behind this method is explained in a panel in our ATtiny816 Breakout Board article that we published in January 2019, starting on page 44 (siliconchip.com.au/Article/11372).

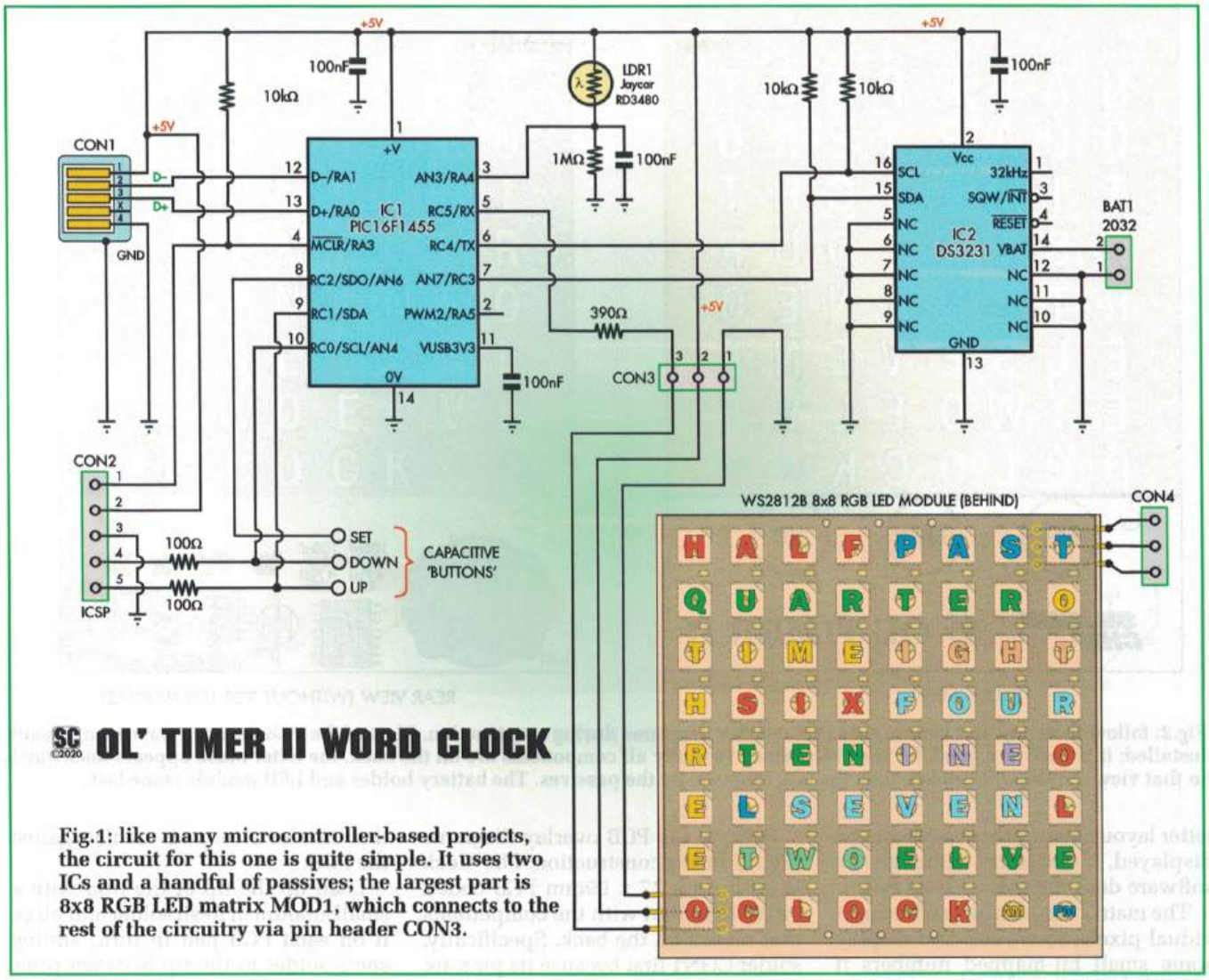
Essentially, the change in capacitance from finger proximity can be measured by clever use of the ADC (analog to digital converter) peripheral. So we have been able to add three 'pushbuttons' without any extra hardware, apart from some PCB tracks.

At the back of the PCB, on the reverse of the touchpads is a copper ground pour. This, combined with the shape chosen for the touchpads, maximises the capacitance change that occurs when it is touched.

These three pads can be used to set the time and alter the clock configuration, with the SET button cycling between several parameters and the UP and DOWN buttons allowing the parameters to be changed.

The USB peripheral on IC1 is also programmed in firmware to behave as a

In keeping with the modern look of the Ol' Timer II, we're producing the PCBs with red, blue and black silkscreens. If someone can produce a wood-veneer silkscreen, then you can produce a truly retro looking clock!



OL' TIMER II WORD CLOCK

Fig.1: like many microcontroller-based projects, the circuit for this one is quite simple. It uses two ICs and a handful of passives; the largest part is 8x8 RGB LED matrix MOD1, which connects to the rest of the circuitry via pin header CON3.

USB-serial bridge. When connected to a serial terminal program, an intuitive configuration menu can be accessed to change the time and other clock settings.

Display

That we have used a microcontroller to control the LED matrix is straightforward enough, but we think the clever part is how the matrix is used to create a readable output capable of displaying words.

Most of the PCB is actually a carefully crafted mask intended to transmit the shape of the letters. Where we want light to shine through, the solder mask and copper layer have been removed, meaning that light from the LED underneath is only diffused by the FR4 fibreglass material in between.

The top copper layer forms a solidly opaque mask, and the solder mask gives a uniform appearance (the alternative here would be a bright silver layer of solder). To reduce spillover from adjacent LEDs, an acrylic mask sits around each LED, further limiting the spread of light.

Since each LED can be lit up to practically any colour in the RGB spectrum, we can illuminate each letter a different colour to differentiate the words, or set the brightness to account for different viewing conditions.

This basic concept is not new, but most of the similar designs we have seen use a much larger matrix. We felt that 8x8 should be enough.

Laying out the letters to display the necessary words was the tricky part. We managed to fit everything in with the help of a spreadsheet, although we did have to fit some words in vertically, which is not something we'd seen done before.

We had a few LEDs left over which were not needed to form any of the words, so we have allocated them to other useful features. The last two 'pixels' at bottom right were free and are well suited to an AM/PM display, so the masks have been designed to show these pairs of letters in a slightly smaller font.

With some clever use of the existing

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siliconchip.com.au/shop

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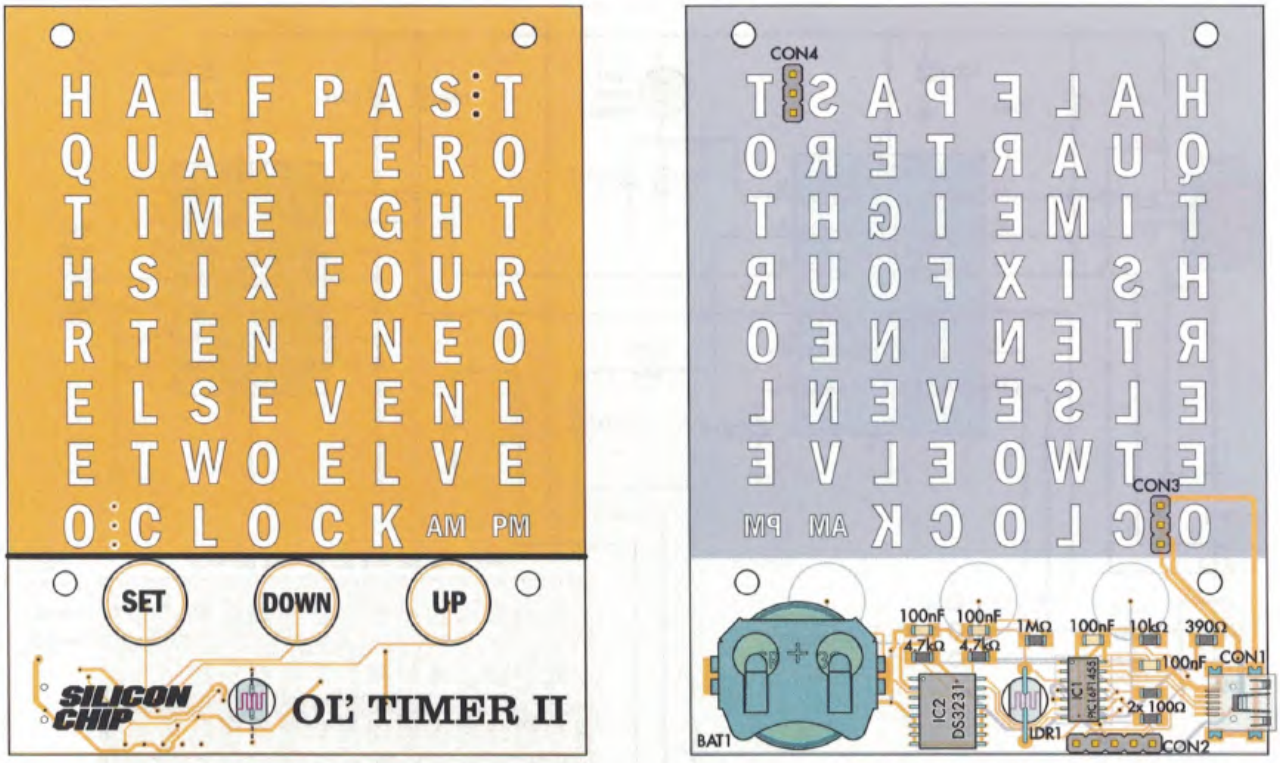


FRONT VIEW

REAR VIEW (WITHOUT RGB LED MODULE)

Fig.2: follow these top and bottom side PCB overlay diagrams during construction. Most of the PCB does not have components installed; it is used as a mask for the LEDs. Since virtually all components are on the back, the letter mask appears backwards in that view. Fit the USB socket, then the ICs, followed by the passives. The battery holder and LED module come last.

letter layout, some other words can be displayed, if necessary, although the software does not make use of this.

The matrix can also be used as individual pixels, so we can also display some small bit-mapped numbers if necessary. We use this to display information when the colour or brightness is being updated by the touchpad controls.

Construction

Like many projects, this one depends on surface-mounted components; not so much due to size, but because it allows the front of the PCB to be unmarred by soldered pads. As such, we suggest that you have some solder flux paste, braid (wick), tweezers and a magnifier on hand, along with a soldering iron, preferably one which can have its temperature adjusted.

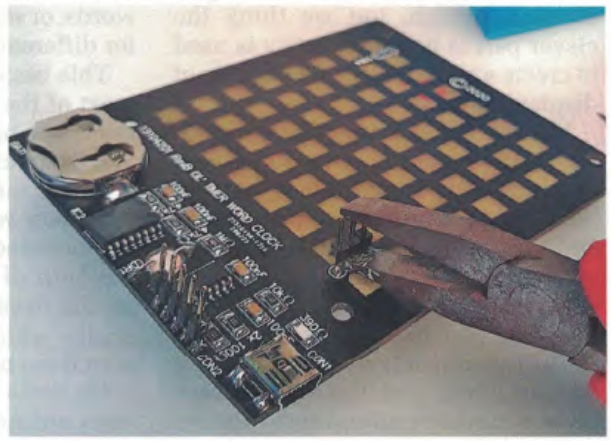
The flux generates a moderate amount of smoke, so use a fume extractor or work outside if possible to avoid breathing in the fumes. A fine-tipped iron is helpful, but even a chisel tip held with its edge vertically should be OK to do the job. We used a 2.4mm chisel tip to build our prototype.

Refer to the PCB overlay diagrams (Fig.2) during construction. The Clock is built on a 77 x 99mm PCB coded 19104201. Start with the components that mount on the back. Specifically, solder CON1 first because its pins are somewhat difficult to access. We've extended its PCB pads to make soldering it slightly easier.

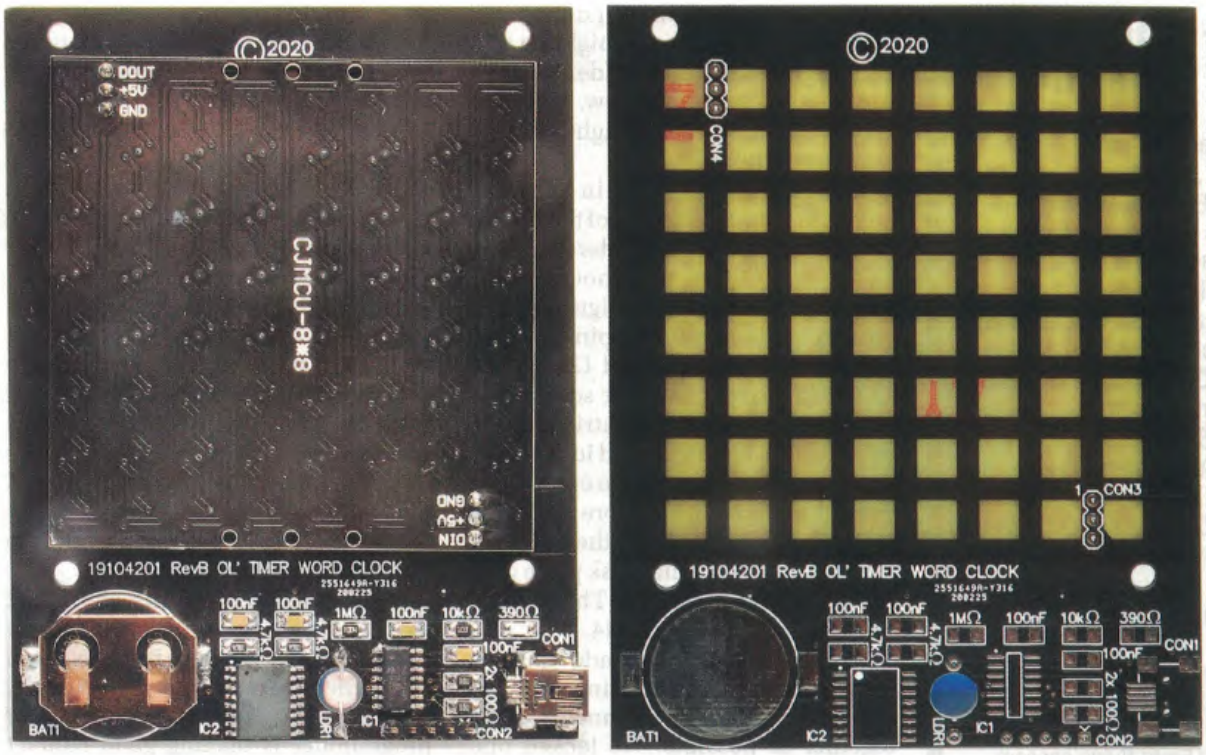
Apply some flux paste to the pads for the USB socket, turn your iron up slightly (if it's adjustable) and line up the socket; the locating pins go into holes on the PCB to aid in its correct alignment. Solder one of the larger mechanical pads on the body, ensuring that the electrical pads are flat against the PCB.

Load up the tip of the iron with a small amount of fresh solder and place it on each PCB pad in turn, adding some solder to the tip between pins. The flux will induce the solder to run off the iron and onto the pins.

Inspect your work with a magnifying glass; it will be much easier to correct this now without other components in place. Use the braid and iron to remove any excess if there is a bridge. There isn't much room to do this, so take your time. Once you are happy with the socket's pins, solder



To remove the plastic holder from the pin headers (after soldering to the main PCB), carefully place a pair of pliers as shown and squeeze. You should repeat this procedure for CON4 too, before soldering MOD1 in place.



At left is the populated PCB with the LED Matrix (MOD1) fitted above. Not seen is the acrylic mask that sits between the two. The photo at right shows the gaps in the solder mask which allow the light to shine through.

the remaining mechanical tabs. The iron can be turned back to its regular setting after this.

Fit the ICs next. IC1 is the smaller, 14-lead part. Apply some flux to the IC's PCB pads and rest the IC on its pads. Check that the pin 1 dot is adjacent to the dot marked on the PCB. Solder one corner pin in place and check that the remaining pins are flat and within their pads. If not, soften the solder with the iron and adjust until they are.

Solder the remaining pins, adding solder to the iron as you go. If you make a solder bridge, leave it for now and ensure that the pins are all soldered before correcting. This will ensure that the IC stays in the correct place.

Use the braid and iron (and extra flux if necessary) to remove any excess solder which is bridging between pins. The technique we use is to apply the flux to the top of the bridge, then press the braid against it using the iron. Gently draw the braid away from the pins after the solder melts and is drawn into the braid.

IC2, the wider 16-pin part, has a similar treatment. Check its orientation then solder one pin. Once it is in the correct location, solder the remaining pins and remove bridges as necessary.

There are four identical 100nF capacitors. They will have no markings and are not polarised. Refer to our photos, the overlay and PCB silkscreen to see where they fit. As with the ICs, apply flux, solder one pin in place, check that it is square, flat and flush against the PCB before soldering the remaining pin.

There are a few different resistor values, so check these against the PCB markings, the photos and Fig.2 before fitting them.

The LDR is a through-hole part, but we have to mount it in an unorthodox fashion to fit in with the other parts. Have a look at the overlay and photos as you read through the explanation.

Sit the PCB face-down on a flat surface, bend the LDR's leads by 90° and place it in the centre of the hole marked LDR1 with the leads aligned vertically. It's not polarised, so it doesn't matter which way it is rotated. Mark on the leads where they cross the pads on each side of the hole, then trim one, using the other to position the part.

Place the LDR back in the hole and solder the shortened lead in place to the adjacent pad. Flip the PCB over and check that the appearance is acceptable and that the LDR is centred and parallel to the PCB before trimming and soldering the remaining lead. It's easier to bend and adjust the leads while only one is soldered.

The battery holder is a larger part, so you might like to turn the iron temperature up. Apply some flux paste to the pads and sit the battery-holder (BAT1) over the top. Ensure that the opening is at the edge of the PCB to allow the battery to be fitted or removed. As for the other parts, solder one pad, then check the alignment and then solder the other pad.

If you need to program IC1 in-circuit, then you can solder a header for CON2 as we have done. But this is

The LED matrix module is connected to the main PCB by two pin headers, with a laser-cut acrylic spacer in-between. It can be fiddly to put this all together and even tougher to disassemble if it is wrong, so proceed carefully.

Parts list – Ol' Timer II

1 double-sided PCB coded 19104201, 77 x 99mm
1 8x8 RGB LED module using WS2812B or similar (MOD1) [Silicon Chip Cat SC5270]
1 set of acrylic case pieces and spacer [Silicon Chip Cat SC5448]
1 ORP12 or similar LDR (LDR1) [Jaycar RD3480, Altronics Z1617]
1 SMD button cell holder to suit CR2032 (BAT1)
1 CR2032 lithium cell (BAT1)
4 100nF 50V X7R SMD capacitors, 3216/1206 size *Code 104*
1 SMD mini type-B USB socket (CON1)
1 5-way male pin header (CON2, optional)
2 3-way male pin headers (CON3,CON4)
8 M3 x 6mm machine screws
4 M3 tapped 15mm Nylon spacers

Semiconductors

1 PIC16F1455-I/SL 8-bit microcontroller programmed with 1910420A.hex SOIC-14 (IC1)
1 DS3231 real-time clock IC, wide SOIC-16 (IC2) [Silicon Chip Cat SC5103]

Resistors (all 1% SMD, 3216/1206 size)

1 1MΩ	*Code 105*
1 10kΩ	*Code 103*
2 4.7kΩ	*Code 472*
1 390Ω	*Code 391*
2 100Ω	*Code 101*

not strictly necessary as it is possible to simply hold the header in place during programming. There are small vias on the pads which help to keep the header aligned.

We should point out that while they are through-hole parts, none of the headers (CON2-CON4) are soldered in the regular manner. Instead, they are vertically surface-mounted onto a set of pads.

In each case, first insert it into a header socket to keep the pins together and aligned (and also provide something to hold onto, as the header will get hot!).

Put some solder flux on the pads and rest the header approximately where it needs to go. Solder one pin in place and check the alignment. If it is only slightly off, you might be able to gently flex it before soldering a pin at the other end of the row, but don't flex it too hard, or it might tear the pads from the PCB.

For CON2, once it is in position, solder the remaining pins of the header and then remove the header strip. For CON3 and CON4, you should check that MOD1 is correctly aligned before soldering the remaining pins.

So once you've tacked CON3 and CON4 in place, check for squareness by trying to fit the LED matrix module over the top. It's also a good idea to test-fit the acrylic mask piece to ensure that everything is aligned before soldering all the header pins. Once they've been fitted, slide the acrylic mask piece over the pins, then fit MOD1. This is then soldered to CON3 & CON4.

It will be tricky to undo this, so take extra care in ensuring that the two boards are parallel and as close together as possible. We tacked one pin, then firmly squeezed the boards together while remelting the solder, allowing the gap to close. Note that the PCB and module won't quite be flush because the LED module also has small capacitors on its surface.

Programming

You don't need to program IC1 if you purchased it pre-programmed. But if you have a blank micro, you need to program its flash memory with the firmware HEX file to get the Clock to work correctly. Download this from our website before proceeding and extract the HEX file from the ZIP package.

You can use a PICkit 3, PICkit 4 or Snap programmer to do this. We used a Snap, but since this does not provide power, you will need to supply power via a USB cable plugged into the USB socket.

Note that the Snap cannot perform high-voltage programming, so if IC1 has had its LVP (low-voltage programming) fuse bit set, the Snap can't clear it. But it will work with a new, blank chip.

Plug your programmer into the ICSP header (CON2). Its pin 1 is closest to the USB socket and marked with a small arrow. If you have not soldered the header for CON2, merely plug a male header strip into your programmer and hold it against the pads of CON2.

We recommend that you use the free Microchip MPLAB X IPE (integrated programming environment) software. Windows, Linux and Mac versions are available from **www.microchip.com/mplab/mplab-x-ide**

The PIC16F1455 is an 8-bit part, so install support for 8-bit parts if queried. Open the IPE, select "PIC16F1455" as the device and choose your tool from the drop-down below this. Select "power target circuit from tool" if you aren't providing 5V via the USB cable. But do not do both.

Click "Apply", then "Connect"; the IPE should indicate that it has found a PIC16F1455 device. You can then use the browse button opposite the Hex File option to choose the .HEX file that you downloaded earlier. Click "Program" to write the .HEX file into the chip's flash memory.

If you run into problems, check that the programmer settings are correct and ensure that power is supplied from either the programmer or a USB cable, but not both. Also, check that your programmer is making good contact with CON2. If holding the header to the board, it might work if you try again.

Setup

If you haven't already done so, connect the Clock to a computer using a mini-USB cable. The first time it's powered up (ie, with IC2's time unset), it should light up showing the words TWELVE OCLOCK AM.

The Clock uses the same IC and USB-serial profile as the Microbridge (May 2017; **siliconchip.com.au/Article/10648**). If you need drivers (which should not be necessary under Windows 10, Mac or Linux), then suitable drivers can be downloaded from **www.microchip.com/wwwproducts/en/MCP2200**

You will need a serial terminal program to complete the setup. We used TeraTerm, although most serial terminal programs, including PuTTY (but not the very limited Arduino Serial Monitor) should work.

Find the device's port and open it. You do not need to worry about the baud rate as the Clock uses a virtual serial connection that ignores that setting. Once connected, pressing the Esc key should bring up the menu.

If at any time you don't know what the setup program is doing, press Esc to return to this point and abort any entry. Refer to screengrabs Screen 1-3 during the setup process. The prompts and responses are quite intuitive.

The first option, "1", sets the time. Press Esc, 1 and then the time in HHMMSS 24-hour form, then press Enter. The time is immediately saved to IC2 and the time display is updated. For example, to set the time to 3:30pm, type the digits 153000 when prompted.

There are also three colours that can be set, for the hours, minutes and AM/PM. These are entered as six-digit hexadecimal codes in the form RRGGBB. These sorts of codes are commonly used on webpages, so are easy to find, even if you don't speak hexadecimal!

We've listed a few common colours and their codes in Table1; these are taken from the officially named HTML colours. If these are not suitable, the website https://htmlcolorcodes.com/ is quite helpful for generating and listing codes.

Thus, to set the colour of the minutes display to red, you would press ESCAPE, 2, FF0000 and press Enter. The colour change takes effect immediately, but does not get saved to non-volatile memory. This is only done when needed to reduce wear and tear on the flash memory.

If you make an error while typing, you can use Delete or Backspace to remove the last character, or press Esc to abort and jump back to the main menu.

There are two different brightness settings. One of these corresponds to the brightness under low light conditions and is controlled by using the + and - keys. These can be pressed at any time to alter the brightness, no matter what the menu is doing.

The < and > keys control to brightness under higher ambient light conditions, and they operate similarly. We found that in indoor conditions, quite low levels were comfortable, so we set the defaults quite low. The software prevents the level being set so low that the display is invisible.

The software does not manage the current drawn by the Clock, nor make requests for power above the 100mA default set by the USB standards. We found that the normal clock display at default brightness levels sat just under 100mA, and rose to near 500mA with the brightness set high during setup (when more than the usual number of segments are lit).

With the brightness set this high, the display is almost too bright to look at, so lower levels are quite adequate.

Still, this should not be a problem, especially if the Clock is to be powered by a 'dumb' USB charger. Even if left connected to a computer, most USB ports will supply 500mA without complaining, enough to keep the Clock running.

To set the Clock brightness to work with a full range of lighting conditions, put the clock in a dark room (what it would be typically exposed to, say, at night) and set the 'low' brightness to a comfortable level using + and -. Then expose the Clock to daytime illumination and set the 'high' brightness with the < and > keys.

Check that the Clock now responds correctly under all light conditions and tweak these further if necessary; the 'low' and 'high' levels will interact to a small degree so you may need to iterate this process a few times.

To save the colour and brightness settings, press Esc and then 5 as per the menu prompt. The current settings are saved to flash memory and will now be loaded every time the Clock powers up.

Table1 - Common hexadecimal colour codes

Aqua	00FFFF	Orange	FFA500
Blue	0000FF	Pink	FFC0CB
Brown	A52A2A	Purple	800080
Crimson	DC143C	Red	FF0000
Cyan	00FFFF	Salmon	FA8072
Gold	FFD700	Sky blue	87CEEB
Grey	808080	Tan	D2B48C
Green	008000	Teal	008080
Indigo	4B0082	Violet	EE82EE
Lime	00FF00	White	FFFFFF
Maroon	800000	Yellow	FFFF00
Navy	000080		

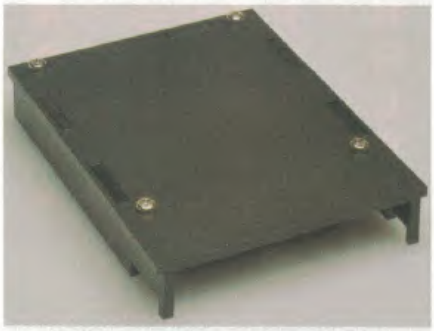
The colour codes here are drawn from the standard HTML colours used on web pages (we don't agree with some of the name choices, but they give you some idea). Note that they may look different on the Clock due to the PCB fibreglass colour and surrounding solder mask.

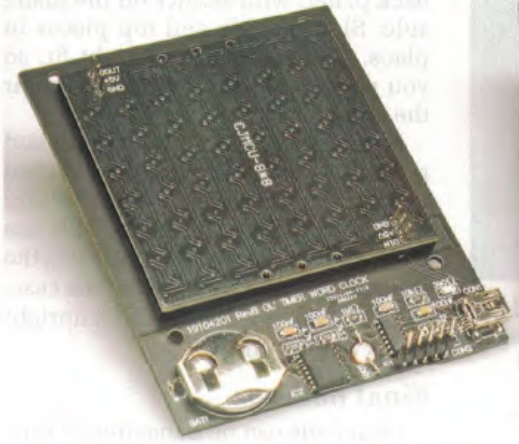
The serial interface has one more trick. If the "q" key is pressed, the debugging mode is turned on. It can be turned off by pressing "q" again or pressing Esc.

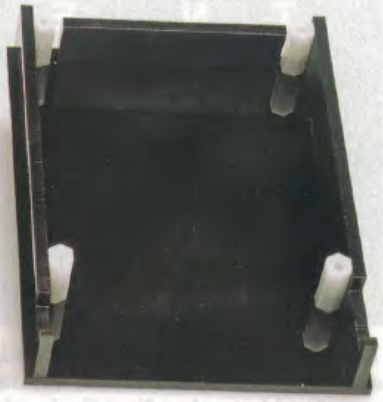
The result is shown in Screen3; the current time, RTC status and intended LED display is scrolled and updated every second. If the unit's display does not look right, this will give you an indication as to what the problem might be. Or, if the time does not appear to be saved or loaded correctly, you will know whether RTC chip IC2 is functioning correctly.

Touchpads

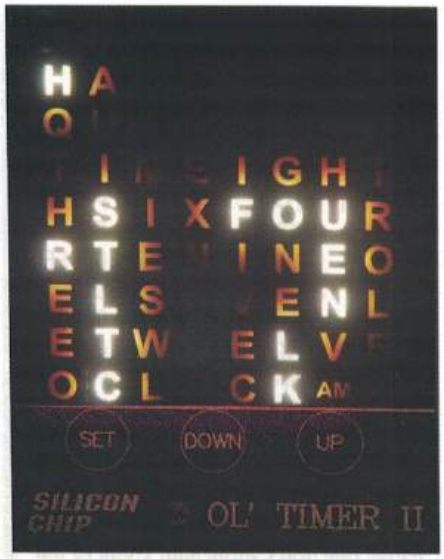
If you don't have access to a computer or USB terminal program, all these parameters can be set using the







The case pieces are assembled from back to front: the spacers are fitted to the back panel before the side pieces are slotted in place, with the main PCB being screwed in from above.



In setting the hours, minutes and seconds, either an H, M or S is seen along with the value as a decimal number (17 here). The real-time clock is updated after you leave the seconds setting.

touchpads. There are fourteen parameters set in turn; these are cycled by pressing the SET touchpad. The current parameter is changed by using the UP and DOWN touchpads.

The pads have to be pressed quite firmly; we deliberately avoided making it too sensitive as it would be quite annoying to have the settings change unintentionally. If you have trouble, try slightly moistening your finger.

The values are shown in decimal for time and hexadecimal for other numeric values (colour and brightness). Apart from the numeric display, some other LEDs are lit to let you know what is being set.

The first three parameters (in order) are the time in hours, minutes and seconds, with the letters H, M or S being shown to indicate this.

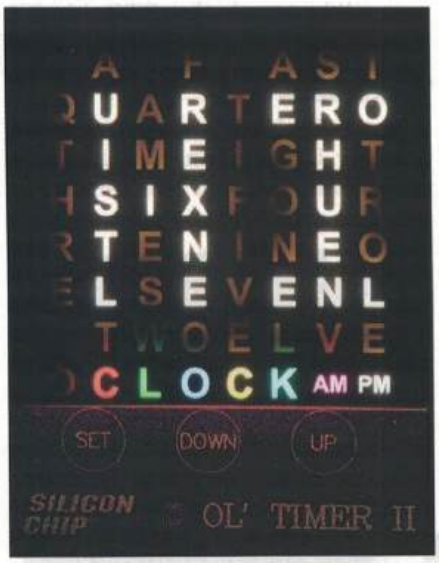
After the seconds are entered, the time is saved. If you make a mistake, the best option is to remove power for a second; there is no other way to avoid saving the time.

This is followed by the hours colour (red, followed by green, then blue) components. The minutes colour and then AM/PM colour follow. The component is shown by, for example, a red H or blue O (for other; ie AM/PM). The top-right LED (a T) shows how the mixed red, green and blue components look.

This is followed by the low brightness "LO" and the high brightness "HI". A palette along the bottom line shows how different colours would look at these brightnesses. The photos on this page show these different displays.

A fifteenth screen shows a red (floppy disk!) save icon. If the UP or DOWN buttons are pressed when this is showing, the colour and brightness settings are saved to flash.

Thus all the parameters can be set, even if you don't have access to a computer or terminal program.



The two brightness settings HI and LO are also set in hexadecimal, although you should simply adjust the level to be comfortable. A palette at the bottom indicates how some colours will look.

Completing assembly

Once you are happy that the clock is working correctly, fit a CR2032 battery to the holder. Check that the time is retained when the power is off. The battery should last close to its shelf life if the Clock is powered most of the time.

Fit the threaded spacers to the large back panel, with screws on the matte side. Slot the side and top pieces in place. The spacers are a tight fit, so you may need to rotate them to clear the side pieces.

Note that the lefthand and righthand pieces are similar, but slightly different to fit around the USB socket or battery holder. Rest the PCB on top and use the remaining screws to secure it to the spacers and the remainder of the case.

The Clock is now able to sit upright on its bottom edge.

Final notes

Coin cells can be dangerous if they are ingested. Thus the Clock should be kept away from small children and babies.

We suspect it would be very difficult to remove the battery from the Ol' Timer II without removing the back of the case, but we recommend not taking any chances with this.

If you wish to be even more cautious, you could secure the battery in place with some glue or silicone sealant. SC

There are nine colour pages, one each for the red, green and blue components of the hour, minute, and AM/PM colour. The displayed colour is in hexadecimal and jumps by 15 steps each press. For a simpler way to set the colours, use the USB terminal.

The settings are not saved by default. You should press the UP or DOWN button when this icon is visible to save the settings to flash memory, meaning they are loaded at power-on.

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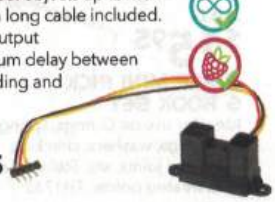

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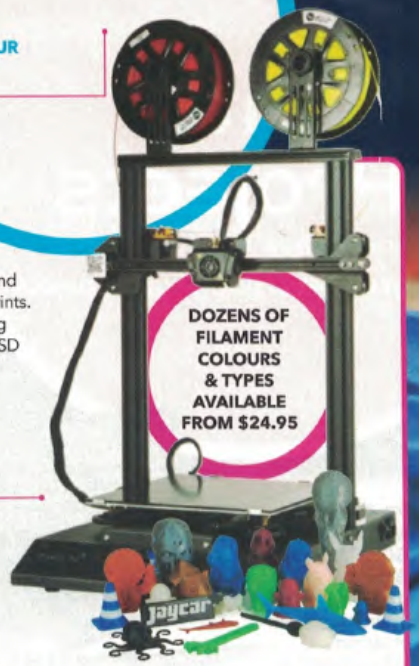

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Station Type	Soldering	Soldering	Soldering & Hot Air	Soldering
Display	Analogue	Digital	LED	LED
Power (W)	48W	60W	300W rework, 60W solder	65W
Temperature Range	150°C to 450°C	160°C to 480°C	50°C to 480°C	200°C to 480°C
Weight	2kg	1.5kg	6kg	1.5kg

Don't forget your solder & flux!

200GM DURATECH SOLDER
60% Tin / 40% Lead. Resin cored. 2 sizes available.
1.00mm NS3010
0.71mm NS3005
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$16.95 EA

SOLDER FLUX PASTE
Provide superior fluxing and reduce solder waste. Non-flammable, non-corrosive. 56g tub. NS3070
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LED ILLUMINATED
CLAMP MOUNT MAGNIFIER
- Powerful 125mm diameter 3 dioptre lens
- Fully adjustable arm with clamp mount
- Interchangeable lens option QM3554

ALSO AVAILABLE:
Rolling Floor Base
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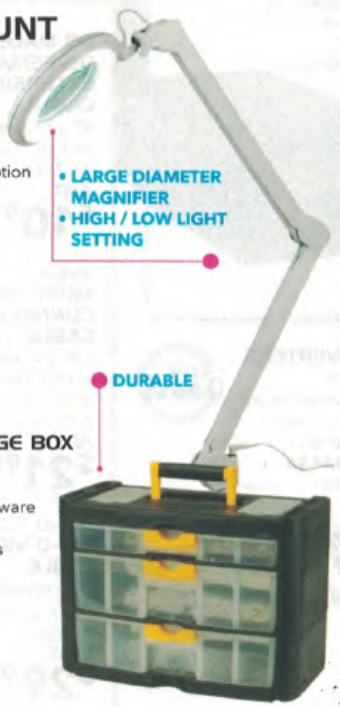
- **LARGE DIAMETER MAGNIFIER**
- **HIGH / LOW LIGHT SETTING**



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Carry your electronic components, parts, hardware and crafting accessories,
- 3 Drawers with dividers
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SILICONE BENCHTOP WORK MAT
- Heat resistant
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PCB HOLDER WITH MAGNIFIER
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- 2X magnifying lens
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LIFETIME GUARANTEE

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600A TRUE RMS AC
- Cat III, 4000 display count
- AC/DC Voltage: 600V/600V
- AC Current: 600A

QM1630
See website for details.
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- Cat III, 4000 display count
- AC/DC Voltage: 600V/600V
- AC/DC Current: 600A/600A

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1000A TRUE RMS AC/DC
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- AC/DC Current: 1000A/1000A

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WITH 4 X RJ45 GIGABIT LAN PORTS

Delivers a massive combined wireless speed of up to 3000Mbps. TouchLink technology to connect to Wi-Fi with a simple touch of the router.

- 400Mbps in 2.4GHz + 867Mbps in 5GHz + 1733Mbps in 5GHz)
- 802.11/a/b/g/n/ac Standards

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ULTRA-FAST GIGABIT ETHERNET SWITCHES

NEW

Provide additional ports to an internet router, firewall, or a standalone network. Backward compatible with 10/100 interfaces.

- 10/100/1000Mbps RJ45 Port
- Automatic connection detection

5 Port YN8395 **$39.95** (Shown)
8 Port YN8397 **$59.95**

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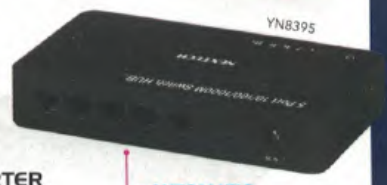

- AUTOMATIC CONNECTION DETECTION
- PLUG AND PLAY

USB 3.0 ETHERNET CONVERTER

Connect an Ethernet cable to an existing USB port. Perfect for Apple® MacBook® and Ultrabooks™. YN8418

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COMPACT

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Dual Band USB 3.0 adaptor connects your laptop/PC wirelessly to the next generation 802.11ac technique with max speeds of 1900Mbps. YN8337

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SOLID NETWORK CABLES

Used for long runs in permanent installations. ACA approved.

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100M ROLL
WB2022 **$1.20/m**
30M POLYWRAP
WB2023 **$29.95**
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100M ROLL
WB2030 **$1.45/m**

FROM $1.20/m

CAT-5 PUNCH-DOWN TOOL & STRIPPER

Strip wire up to 5-6mm, and doubles as a punch-down tool for 110/88-type terminals with blade. TH1738

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RJ45 MODULAR PLUGS

Packet of 10 RJ45 plugs for stranded and solid CAT6 cable. PP1447

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2.5" USB 3.0 HDD ADAPTOR WITH CASE

Connect a 2.5" SATA 6G hard drive to your computer with transfer speeds up to 5Gbps. USB powered. XC4152

ONLY $29.95

USB 3.0 SATA HDD DOCKING STATIONS

Connect 2.5" or 3.5" SATA hard drives to your computer. Plug and play technology. USB 3.0 for fast data transfer.

- Transfer Rate: 430Mbps
- HDD capacity: 8TB

Single XC4687 **$49.95** (Shown)
Dual XC4689 **$64.95**

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2 BAY USB 3.0 SATA HDD RAID ENCLOSURE

Have your files backed up. Tool less & driverless. Supports 2.5" and 3.5" HDD.

- Raid 0, Raid 1, JBOD, Spanning
- Up to 5Gbps transfre rate
- Capacity: 8TB Per Bay
- 215(L) × 135(W) × 114(H)mm

XC4688

JUST $99

RS-232 DB9M TO USB CONVERTERS

Connect a variety of RS-232 devices to your modern computer with these adaptors.

To USB Adaptor
XC4927 **$27.95** (Shown)
To USB 1.5m Lead
XC4834 **$29.95**

FROM $27.95

USB PORT TO RS-485/422 CONVERTER

Up to 480Mbps data transmission. Automatically detects serial signal rate. XC4136

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USB 3.1 TYPE-C CONVERTERS

NEW

Use to take advantage of high performance USB Type-C connectors on new PCs, Macs® and Chromebooks to convert to an existing VGA or HDMI signal.

To VGA Signal XC4931 **$34.95**
To HDMI Signal XC4933 **$49.95** (Shown)

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NEED A PC LEAD?

WE STOCK A HUGE RANGE OF COMPUTER LEADS. LISTED BELOW ARE JUST SOME OF THE MOST POPULAR ONES.

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D9 MALE TO D9 FEMALE EXTENSION CABLE

All pins wired straight through. 1.8m long. WC7534

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DB15HD male to DB15HD male. 2.0m long. WC7586

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DVI-D TO DVI-D VIDEO CABLE

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YOUR DESTINATION FOR ON THE GO CHARGING.

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Multi State Battery Chargers

All-in-one chargers which have multiple charge settings to suit different sized batteries and charging requirements. Capable of recharging the battery and maintaining the charge state indefinitely, they are particularly well suited to being continuously connected to a battery. Choose between mains powered chargers for workshop use and DC-DC models for in-vehicle or marine use. See website for full details.

MB3902
ONLY $29.95

MB3611
ONLY $99.95

MB3621
ONLY $369

	MB3902 NEW	MB3611	MB3621	MB3940 NEW
Output Voltage(s)	6/12VDC	6/12VDC	12VDC	12VDC
Max Output Current	870mA	1A/4A	30A	20A
Multi Stage	7	4	5	6
Battery Support	Sealed, Gel, AGM or Flooded Lead (6/12V, 1.2Ah-26Ah), LiFePO4 (12.8V, 2Ah-15Ah)	Wet, Gel cell, AGM and LiFePO4 (5Ah-120Ah)	Lead acid, AGM and LiFePO4 (50Ah-300Ah)	Lead acid, AGM, Calcium, GEL or LiFePO4 batteries (50Ah to 300Ah)
Type	Mains Powered	Mains Powered	Mains Powered	DC-DC
Special Features	IP65 Dust and weatherproof rated.	IP65 Dust and weatherproof rated, LCD display.	IP65 Dust and weatherproof rated. Intelligent charger can operate with or without load.	IP65 Dust and weatherproof rated. Dual input: solar and/or alternator/car battery.

MB3940
ONLY $219

- **FOR USE IN VEHICLES**
- **DUAL INPUT: SOLAR AND/OR ALTERNATOR/CAR BATTERY**

Battery management & protection

LEAD ACID BATTERY CONDITIONER

Removes or reduces sulphation which kills batteries. One bottle will do up to a N7OZ size battery (4WD, boat, truck, etc.)
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ONLY $9.95

BATTERY DISCHARGE PROTECTOR

Protects your vehicle battery by switching off appliances before the battery voltage drops to an unrecoverable level.
- Operating voltage: 12VDC
- Max. switching current: 20A
- Interrupting voltage: 10.4 - 13.3VDC

AA0262

ONLY $46.95

BATTERY ISOLATION SWITCHES

High current rated battery isolation switches for high power applications. They feature high quality construction with huge bolt down terminals for electrical connection.
12V 120A
SF2245 **$19.95** (Shown)
12V 500A
SF2247 **$69.95**

FROM $19.95

12VDC LEAD ACID BATTERY TESTER

Quickly, easily, and accurately measures the cold cranking amps capability of the vehicle starting battery.
- Voltage Measure Range: 6-30VDC

QP2261

ONLY $79.95

DEEP CYCLE SLA BATTERIES

Excellent for high capacity versatile storage. Leakproof and completely sealed, ideal for solar power, 4WD, camping etc.
12V 26Ah SB1698 **$129**
12V 38Ah SB1699 **$199**
12V 100Ah SB1695 **$379*** (Shown)
*Limited stock. Check store for stock availability.

SEE IN-STORE OR ONLINE FOR OUR FULL RANGE OF SLA BATTERIES.

FROM $129

DUAL-CHANNEL LI-ION / NI-MH BATTERY CHARGER

Charges Li-ion, LiFePO4, Ni-Cd, Ni-MH from AAA to D sizes. Supplied with USB and in-car cigarette lighter power leads.
MB3635

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HIGH CAPACITY ENELOOP PRO NI-MH BATTERIES

Can be recharged 500 times, and will retain up to 85% of their capacity after a year in storage. Pre-charged.
900MAH AAA PK4
SB2938
2450MAH AA PK4
SB2936
ALSO AVAILABLE:
Eneloop Charger
MB3563 **$49.95**

SB2936

ONLY $32.95 EA

LI-ION RECHARGEABLE BATTERIES

A range of nipple cap and solder tab batteries in varying capacities.
SB2300-SB2319
See website for full range.

FROM $10.95

AA BATTERY HOLDERS

2 x AA Side by Side
PH9202 **$1.45**
2 x AA Switched Battery Enclosure
PH9280 **$3.95**
See website for full range.
ALSO STOCK HOLDERS FOR 18650 (ETC.) CELLS

FROM $1.45

YOUR DESTINATION FOR DIY & RASPBERRY PI PROJECTS.

Think. Possible.

MAKING RASPBERRY PI PROJECTS POSSIBLE
Whether you're just starting with Raspberry Pi for the first time, or you want to expand upon a Raspberry Pi project, we have an extensive range of accessories to make that possible.

RETRO ARCADE GAME CONSOLES FOR RASPBERRY PI

Let the games begin with these exciting retro arcade consoles. Simply install a Raspberry Pi 3B+ (XC9001 **$89.95** Sold Separately), into the console, insert a Retropie installed micro SD card (XC9031 **$24.95** Sold Separately), copy over some games and you are ready to play. See website for detailed install instructions.

10" SCREEN RETRO ARCADE GAME CONSOLE
- Includes a joystick and 6 buttons.
- Built-in speaker

XC9064 **$249**

RETRO ARCADE GAME CONSOLE
- Connects to your TV, computer or projector with HDMI or VGA cable
- 2 Player console

XC9062 **$169**

ONLY **$249** XC9064

XC9062 ONLY **$169**

JUST **$89.95**

SINGLE BOARD COMPUTER

RASPBERRY PI 3B+

Tiny credit card size computer.
- 1.4GHz 64-bit quad-core processor
- Dual Band 2.4GHz & 5GHz Wireless LAN
- Bluetooth® 4.2 technology with BLE
- Faster processing and networking
- Supports Power-over-Ethernet (with separate PoE HAT)

XC9001

RETROPIE OS ON 16GB SD CARD FOR RASPBERRY PI
Preloaded with RetroPie, and auto-installs when used for first time. Supplied with an SD card adaptor XC9031
Note: Best compatible for Raspberry 3B/3B+

ONLY **$24.95**

ALSO AVAILABLE:
Raspberry Pi Beginners Guide 2nd Edition
BM7164 **$27.95**

ONLY **$9.95**

RETRO NES STYLE CONTROLLER
SNES layout. Features A/B/X/Y buttons, start, select, and direction controls. Easily configurable, USB powered. XC4404

RETRO NES CASE
Perfect for building a Raspberry Pi 3/3B+ based emulator.
- HDMI, 3.5mm, and micro USB (power) access
- USB Ports: 4 (Standard, Type -A)

XC4403

ONLY **$39.95**

RETRO GAMING WITH RASPBERRY PI BOOK
This book shows you how to set up your Raspberry Pi for retro gaming, learn to program retro-style games, build a portable console, arcade cabinet, pinball machine and more. 164 pages. BM7166

ONLY **$34.95**

FROM **$3.95**

GREY VENTED ABS ENCLOSURES
Protect your project from unwanted fingers or objects.
- Satin textured finish
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- Snap-fit assembly

40 x 40 x 20mm HB6114 **$3.95**
60 x 60 x 20mm HB6116 **$5.45**
80 x 80 x 20mm HB6118 **$5.95**

HEATSINK PIN GRID ARRAY
An aluminium heatsink with adhesive thermal transfer tape. Suitable for Rasberry Pi and other BGA devices. HH8581

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19MM IP67 METAL PUSHBUTTON SWITCHES
Durable and stylish stainless steel switch with LED illumination.
- 12V LED Illumination
- DPDT Momentary action
- Spade or solder connection

Red DPDT SP0800 **$19.95**
Blue DPDT SP0802 **$19.95**
Green DPDT SP0804 **$19.95**
Blue SPDT SP0810 **$20.95**

FROM **$19.95**

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LIGHT DUTY HOOK-UP WIRE PACK
Quality 13 x 0.12mm tinned hook-up wire on plastic spools. 8 rolls of different colour included. 25m on each roll. WH3009

TECH TALK:

Light Emitting Diodes

- **Luminous intensity (IV) does not represent total light output from an LED. Both the luminous intensity & the spatial radiation pattern (viewing angle) must be taken into account**
- **If two LEDs have the same luminous intensity value, the lamp with the larger viewing angle will have the higher total light output**

STANDARD LEDS
Available in 3 different sizes & colours. Waterclear lens. 100mA.

3mm		5mm		10mm	
Green	ZD0125	Green	ZD0177	Green	ZD0208
Blue	ZD0134	Blue	ZD0183		
White	ZD0144	White	ZD0196		

TRI-COLOUR LED
5mm size. Red, green & blue. Waterclear lens. 100mA. ZD0269

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Looking for other projects to do?

See our full range of Silicon Chip projects at:
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THE CHAMP 0.5W AUDIO AMPLIFIER KIT
Uses the LM386 audio IC, and will deliver 0.5W into 8 ohms from a 9V supply making it ideal for all those basic audio projects. PCB and electronic components included.
- 46(L) x 26(W)mm

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Learn everything about component recognition and basic electronics with this comprehensive kit. Kit includes DMM case, LCD, solder, battery, test leads, PCB, comprehensive 18 page manual and components.
- 67(W) x 123(H) x 25(D)mm

KG9250

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YOUR DESTINATION FOR ARDUINO.

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MAKING ARDUINO PROJECTS POSSIBLE
We carry an extensive range of Arduino-compatible boards, modules, shields, and accessories to make your next Arduino-based project possible.

MAKE YOUR PROJECTS: Wireless

ESP32 MAIN BOARD WITH WI-FI & BLUETOOTH® COMMUNICATION

Dual core microcontroller equipped with Wi-Fi and Bluetooth® connectivity. 512kB of RAM, 4MB of flash memory and heaps of IO pins. XC3800

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UNO BOARD WITH WI-FI

Includes a traditional Arduino® UNO chip & layout as well as an ESP8266 chip to connect your projects to the cloud without the need for additional modules. XC4411

ONLY **$39.95**

MEGA BOARD WITH WI-FI

An Arduino® + Wi-Fi Dual board that includes a traditional Arduino chip + layout as well as an ESP8266 chip to connect your projects to the cloud. XC4421

JUST **$59.95**

More shields & modules

BLUETOOTH® V4.0 BLE MODULE

Brings the latest Bluetooth® 4.0 standards to your Arduino® project allowing two-way wireless communication between Arduinos. Includes antenna.
- 1.9-3.6VDC operating voltage
- Controlled via SPI.

XC4522

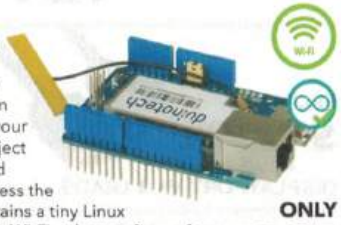
JUST **$29.95**

ESP-13 WI-FI SHIELD

Uses the powerful ESP8266 IC and has an 80MHz processor. An excellent way to get into the Internet of Things. Integrated TCP/IP stack. Simple AT command interface with Arduino main board. XC4614

ONLY **$39.95**

YUN WI-FI SHIELD



Allows you to easily program and operate your Arduino® project over Wi-Fi and allow it to access the Internet. Contains a tiny Linux computer with Wi-Fi, ethernet & USB. XC4388

ONLY **$69.95**

More ways to connect wirelessly

RF TRANSCEIVER MODULE

Adds a versatile 433MHz radio to your Arduino® project allowing two-way wireless communication between Arduinos. Includes antenna.
- 1.9-3.6VDC operating voltage
- Controlled via SPI.

XC4522

JUST **$19.95**

433MHZ WIRELESS MODULES

Pre-built 433MHz wireless transmitter / receiver modules. Feature ASK encoding. Ideal for devices using short data bursts such as remote controls, trigger pulses etc.

Transmitter ZW3100 (Shown)
Receiver ZW3102

JUST **$13.95 EA**

2.4GHZ WIRELESS TRANSCEIVER MODULE

Based on the NRF24L01 transceiver IC, this module allows communication on the license free ISM band. Supports on-air data rates of up to 2Mbps. XC4508

ONLY **$9.95**

INFRARED MODULES

These modules allows you to send/ receive data over infrared. Use the receiver (XC4427) to read signals sent by most IR remote controls, or pair with the transmitter (XC4426) to make a universal remote control.

Transmitter XC4426 **$4.95**
Receiver XC4427 **$4.50**

FROM **$4.50**

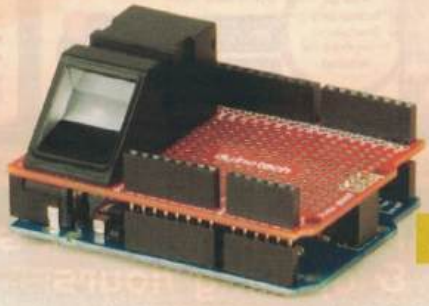
PROJECT: Arduino® Keyboard Emulator WITH FINGERPRINT LOGIN

SEE PARTS & STEP-BY-STEP INSTRUCTIONS AT:
www.jaycar.com.au/fingerprint-login
See other projects at www.jaycar.com.au/arduino

Tired of entering your password each time you access your computer at home or work? Use our completely extensible fingerprint login system project. Using the Leonardo compatible board and our fingerprint sensor, you will be able to log in to your computer with only a thumbprint. Use the Fingerprint for secure features such as logging in, opening the browser, or reading your secret documents. What's more, you can also add more modules such as joysticks or keypads to further extend your Arduino keyboard emulator system, right at your fingerprints!

SKILL LEVEL: Easy
TOOLS: Soldering Iron
WHAT YOU WILL NEED:

1 x Leonardo R3 Development Board	XC4430 **$29.95**
1 x Prototyping Board Shield	XC4482 **$15.95**
1 x Fingerprint Sensor Module	XC4636 **$49.95**



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$69.95
SAVE 25%
KIT VALUED AT $95.85

Upgrade Your Project!

FEEDBACK BUZZER

Alert on password or thumbprint failure, to deter others trying to use your device. AB3459

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JOYSTICK CONTROLLER

Use a joystick to control your mouse. XC4422

JUST **$5.95**

MINI REED SWITCH

Lock your PC as soon as something is removed from your desk. LA5074

JUST **$7.50**

EXTENDED KEYPAD

Add up to 16 macro buttons to assign to your computer once you have logged in. XC4602

JUST **$9.95**

What's NEW

ONLY
$13.95

5MP HIGH DEFINITION WEB CAMERA

Clear crisp 1080p HD video for Skype, Zoom, or other video conferencing applications.

- FHD auto-focus for brighter pic
- Auto-adjusts for crystal clear image even in low light
- Double mic stereo sound

QC3207

ONLY
$129

DUINOTECH ATTINY85 MICRO USB DEVELOPMENT BOARD

Features an ATtiny85 8-bit microcontroller that you can program using the Arduino IDE. 8k Flash Memory.

- 6 x I/O connections
- Integrated 5V Regulator

XC3940

9-IN-1 MULTIFUNCTION TYPE-C USB HUB

Connect just about anything to your Macbook® or latest laptop. Connections include an HDMI output with 4K support, an RJ45 Ethernet port for speeds up to 1000Mbps, SD and microSD memory card slots, 3.5mm stereo audio in and out, and 2 x USB3.0 hot-swap capable ports to connect computer peripherals, hard drives up to 1TB, etc. XC4975

ONLY
$99.95

FROM
$19.95

DISPLAYPORT V1.4 LEADS

Used to connect a video source to a display device such as a computer monitor, TV or projector. Supports up to 8K@60Hz video resolution.

Plug To Plug 1.8m	WQ7460	**$19.95**
Plug To Plug 3.0m	WQ7462	**$29.95**
Plug To Mini Plug 1.8m	WQ7464	**$29.95**

EXTRA LONG TV COAX CABLES

Super flexible coax leads that makes it easier to run through entertainment cabinets and along skirting boards, etc.

- Quality RG6 quad shielded coax cable
- F-Plug to F-Plug

10m WV7468 **$24.95**
20m WV7470 **$34.95**

FROM
$24.95

ONLY
$2999

12 CAMERA KIT

16CH 4K NVR KIT WITH 8 X 4K PIR SPOT LIGHT BULLET + 4 X 4K PIR CAMERAS

Protect your property with this multi-camera, wired surveillance system with everything you need to do-it-yourself or have it professionally installed. High quality video allows you to see greater detail to positively identify security issues.

- Up to 150 days recording with dropbox capability to ensure important footage is available for review.
- Swann's True Detect™ heat & motion-based PIR detection reliably captures & records activity
- Records audio for additional layer of security

QV9099

2TB HDD

Works with amazon alexa
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Download on the App Store

4K UHD

NEW TRUE DETECT

Swann

5W GME UHF RADIO WITH BLUETOOTH® COMMUNICATION

iOS and Android apps available to configure, update and customise the radio. 10-16VDC input.

- 80 FM CB radio channels
- 50 Ohm antenna impedance
- Bluetooth® enabled allows creating and sharing of lists.

DC9059

GET IT ON Google Play
Download on the App Store

ONLY
$549

XRS-370C
GME

4G GPS VEHICLE TRACKER

Locate and track the whereabouts of your vehicle in realtime via the Internet on a computer, Smartphone or Tablet.

- SMS location & tracking return
- Rechargeable battery
- GPS & GSM module
- Geo Fence Alarm

4G Sim card needed, can be purchased separately from Telstra, Optus, etc.

- **BUILT-IN MICROPHONE**
- **ENGINE KILL FUNCTION**

LA9038

ONLY
$229

TERMS AND CONDITIONS: REWARDS / CLUB MEMBERS FREE GIFT, % SAVING DEALS, & MEMBERS OFFERS requires ACTIVE Jaycar Rewards / membership at time of purchase. Refer to website for Rewards / membership T&Cs. IN-STORE ONLY refers to company owned stores and not available to Resellers. Page 1: Bundle Deal: 1 x KM1097 + 1 x XC4410 for $39.90. Page 7: Club Offer: Arduino Keyboard Emulator with Fingerprint Login project includes 1 x each of XC4430, XC4482, XC4636 for $69.95.

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Arrival dates of new products in this flyer were confirmed at the time of print but delays sometimes occur. Please ring your local store to check stock details. Occasionally there are discontinued items advertised on a special / lower price in this promotional flyer that has limited to nil stock in certain stores, including Jaycar Authorised Resellers. These stores may not have stock of these items and can not order or transfer stock. Savings off Original RRP. Prices and special offers are valid from catalogue sale 24.06.2020 - 23.07.2020.

SERVICEMAN'S LOG

Well-designed thoughtlessness

Dave Thompson

A recurring theme for these columns as of recent times is the prevalence of designers who, whether intentional or not, put a lot of thought into not thinking when designing devices.

Items Covered This Month

- Misanthropic designers producing ill-considered designs
- HP8595 spectrum analyser repair
- 3A USB charger repair

*Dave Thompson runs PC Anytime in Christchurch, NZ.

Website: www.pcanytime.co.nz
Email: dave@pcanytime.co.nz

People of a certain age may recall an English sitcom named "The Fall and Rise of Reginald Perrin". I'm not talking about the insipid recent remake, but the original show, which aired way back in the mid-70s.

The premise of the show was the hum-drum life of an ordinary, middle-class, middle-management worker and his eventual descent into mid-life crisis. He wanted more, and ended up re-inventing himself.

The show was satire, and an indictment of then-British society (and her colonies). It took every opportunity to skewer the class system, the unions, the nationalising and de-nationalising of various industries and much more.

One of several running gags involved the trains, where because they always ran late, Reginald was always late for work. In the first series, he was always 11 minutes late. In series two, he was always 17 minutes late and in series three, 22 minutes late.

He always offered a different excuse for his lack of punctuality, and these excuses were increasingly outlandish, such as: "seasonal manpower shortages, Clapham Junction", or: "Seventeen minutes late, water seeping through the cables at Effingham Junction."

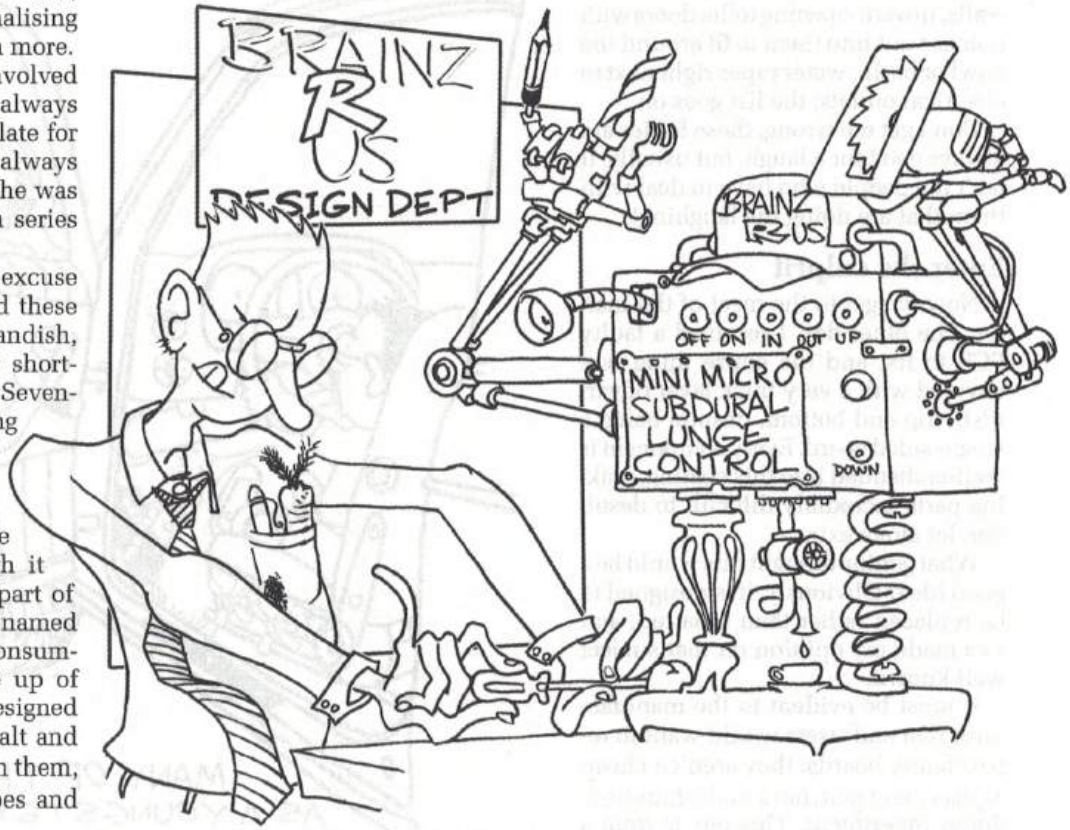
Without spoiling it for anyone who wants to watch the show (I recommend it, though it isn't everybody's cup of tea), part of the storyline involved a shop named Grot. A sly dig at rampant consumerism, Grot's stock was made up of items that were purposely designed to be bad or useless, such as salt and pepper shakers with no holes in them, non-stick glue, elastic tow-ropes and square rugby balls.

I mention this, admittedly in a rather long-winded lead-up, because recently I've been working on some items that could have come from this shop!

Over the years I've regularly called out what I see as lousy design, and I'll keep doing it, because it often seems the person who designed the machine, appliance or manufacturing method has no idea of how the appliance, machine or manufacturing method will actually be used in real life.

Examples include the light on my vacuum cleaner that shines up the wall, rather than on the floor, or the lawnmower that doesn't cut grass short enough and has handles and levers that protrude wider than the cutting track of the mower, making it difficult to mow right up against a wall.

Another example is the pickup selector switch on my Fender Telecaster; it is almost impossible to actuate when in the bridge pickup position because it is



~THE PERSON WHO DESIGNED THE MACHINE ETC HAS NO IDEA HOW IT WILL BE USED IN REAL LIFE

almost hard-up against the tone knob – a design flaw that has persisted since the late 50s. (For those pedants who are preparing to flame me, like many I flipped my Tele's tone-plate around for easier access, swapping the volume and tone pots).

And don't get me started on car engineering! Some cars have the battery under the driver's seat, so you have to remove the seat to replace it. One gets the impression that after the initial prototype rolled out, the engineers discovered that they had forgotten to include a battery and so they had to scramble to find a place to put it!

Many of the cars I drove as a youngster had steering-wheels that obstructed the view of the instruments, and in one car I test-drove, I had to sit at an awkward angle because the steering wheel and pedals weren't in line.

And the number of times I have needed triple-jointed limbs or specially-made tools just to be able to access nuts and bolts to disassemble machinery to get to faulty parts...

It's a miracle that any of these designs get put into production with these quirks. Indeed, there are web pages and YouTube channels dedicated to this subject: stair-wells heading into brick walls, inward-opening toilet doors with notches cut into them to fit around the bowl or basin, water pipes right next to electrical outlets; the list goes on.

Don't get me wrong, these follies are always good for a laugh, but usually, it isn't the people who have to deal with them that are doing the laughing!

Enter the culprit

Now we get to the meat of the matter. The other day, I received a faulty PCB to fix, and the entire thing was covered with a very thick layer of varnish, top and bottom, despite being a single-sided board. Every component is well-embedded into this coating, making parts incredibly difficult to desolder, let alone extract.

What genius thought this would be a good idea? Obviously, it is designed to be replaced rather than repaired, and I've made my opinion on that subject well known.

It must be evident to the manufacturer that end-users would want to repair faulty boards; they aren't a cheap replacement part, but a multi-hundred-dollar investment. This one is from a heavy-duty welder, which no longer held its output. Shipping the welder would have cost more than a new one is worth, so it made sense to send the faulty board (swapping the board fixed the welder, so we know it is at fault).

SOME CARS HAVE THE BATTERY UNDER THE DRIVER'S SEAT

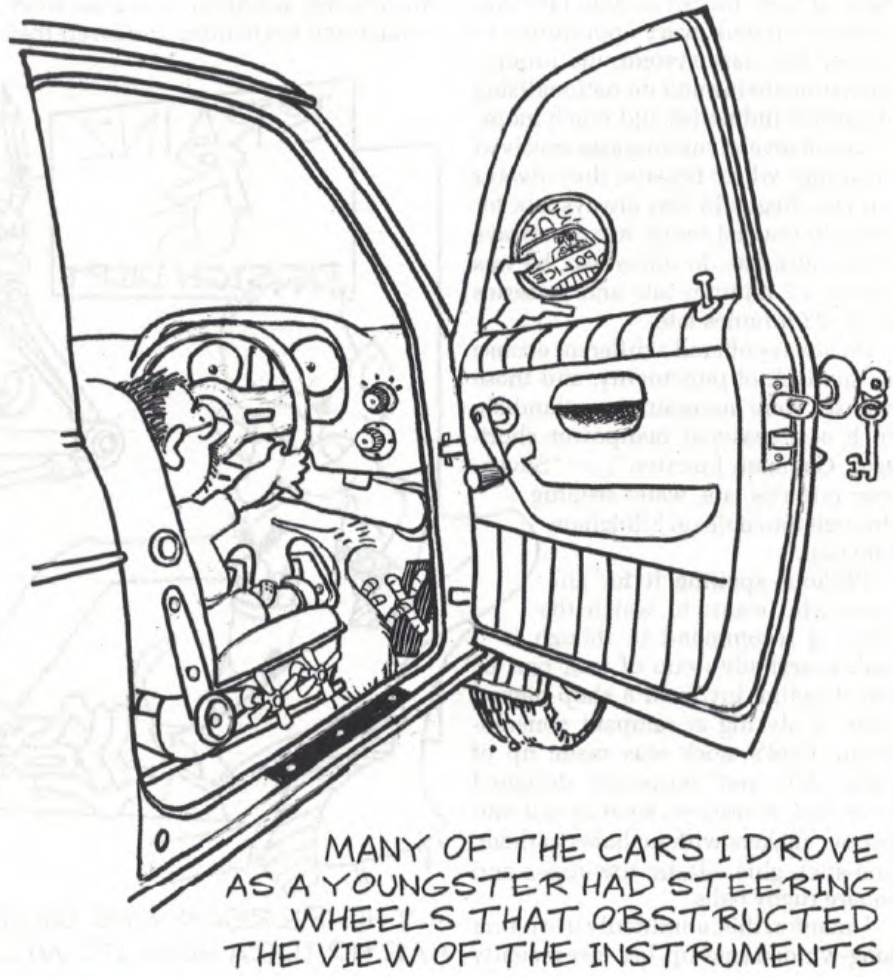
The usual suspects are capacitors, semiconductors or simply solder joints gone bad, but working to resolve any of these problems becomes a major mission due to the varnish coating. One saving grace is that the customer supplied a circuit diagram for the board, and while components on the PCB were clearly marked, it always helps to have a circuit diagram for troubleshooting.

When I encounter a coating like this, the first thing I do is see if I can soften it using solvents. None of the solvents I have touched it. Next is cautiously-applied heat. While a proper heat gun is ideal, I tend to use my desoldering heat gun more these days, as it is easier to control and aim.

I found an unpopulated corner of the board and judiciously applied heat to the area to see if I could make a dent (so to speak) in the varnish. I couldn't. It didn't even get softer; it just got hotter! It turns out, though, that I could melt it with my soldering iron, so that's what I did. Messy, but effective.

That partially solved one problem: getting to the soldered connections on the bottom of the board. But I still had to deal with the component side. Desoldering the leads below was one thing; extracting the components was another.

The first thing I did was to check the soldering on the bottom of the board. Though the varnish was thick, it was


MANY OF THE CARS I DROVE AS A YOUNGSTER HAD STEERING WHEELS THAT OBSTRUCTED THE VIEW OF THE INSTRUMENTS

mostly clear, so a visual inspection was possible.

Like many such boards, there are multiple, well-tinned heavy tracks for the likes of Earth returns and power supply paths. Welders generally boast serious current-handling capabilities, so the boards have to be up to supplying that current without sagging and compromising the welds.

Where there is resistance, there is heat, and as these boards would heat up and cool down regularly, they will expand and contract. This makes any physical connection a potential weakness. As the resistance of a bad joint increases, so does current and heat, and the cycle continues until something eventually gives.

In many ways, it is better for the serviceman to get a board that has utterly failed; at least the faults (or the consequences of the faults) are patently obvious. Intermittent or partial faults make things more difficult, as does not having the ability to bench-test the board.

Several other satellite boards drive this particular controller, and without those, I can't test the board at normal operating levels. I can test each component though, and the overall physical integrity of the board, which is the process I had to use.

There were some very large, heaped solder joints which looked a bit dodgy – this is typical of every high-current power supply board. But I saw no obvious faults like overheated tracks, discolouration of the board or any other visual clues to explain the failure.

I burned through the varnish over several of the more dry-looking joints and cranked up my heavy-duty soldering iron to reflow them, but overall the board looked well-made, and the joints generally were physically sound. So I moved on to check the components.

Component checking

Six large capacitors dominate the landscape of the board. I could measure them in-circuit using my Peak ESR tester, but I prefer to do my component testing off-board, just to be sure.

At least these caps were relatively easy to remove because I could get some purchase onto them. I did have to first cut through the fillet of varnish around the base of each one using a razor blade; a task made more difficult by the proximity of other components.

Still, I got them out, and though it was hard to tell visually whether the goop coating the outside of some of them was leakage or runs in the varnish itself, it proved to be the varnish. All the caps measured very close to their stated values, and the ESRs also read very low.

So I moved onto the handful of smaller electrolytic capacitors and a dozen or so high-voltage ceramic types; I removed them the same way, and they all tested fine.

I also pulled a medium-sized transformer from the board and measured it for resistance; the figures I took from the primary and secondary corresponded roughly to the turns ratio supplied on the schematic (no other specs supplied). But I was more interested in shorts or open circuits, of which there were none. A megger check also proved there was no breakdown in the windings or insulation.

The board has three 24V 10A relays mounted on it and these I tested by clearing the varnish from their terminals on the track side of the board and soldering test leads to their normally-open contacts and coils. I downloaded the data sheets and used my bench supply to raise and lower the voltage, testing each relay's current draw and operation and drop out voltages.

I connected my multimeter's buzzer across the terminals; while not technically a perfect indicator of the electrical condition of the contacts, my musical ear can detect even subtle variations in the frequency of the tone, which changes with resistance. Any deviation from the closed-circuit tone (with the meter leads shorted, for example) means there is resistance in the circuit.

On these relays, the buzzer tone remained the same, indicating no significant changes in contact resistance. Again, this is not a definitive test for contact integrity, but adequate for my purpose.

Semiconductors were my next target, and this board boasts many different types.

Here I had to cut some corners; while the relay driver Mosfets and the large, paired diodes in the voltage multiplier section were relatively easy to remove and test, the smaller DO-35-sized zeners and regular diodes were in almost every case totally enclosed in varnish. They would likely be impossible to remove without damage.

All I could do was clear the varnish underneath (there was a lot of varnish-clearing going on!) and measure them with my semiconductor tester. As this automatically detects and takes into account whether they are in-circuit or not, I had to trust it was doing its job correctly.

There was nothing suspicious in my measurements with any of the diodes. All the zeners measured as-rated, and the other identical types all had very similar breakdown voltages, which in itself means nothing other than that no individual component stood out as a potential problem source.

Measurements of the three IRFZ24 Mosfets did show some discrepancies, so even though not a smoking gun, I decided to replace them. They are as cheap as chips anyway (LOL!) and as the TO-220 packages stand proud of the board, they are easy (relatively!) to remove and refit.

There is one small TO-92 type NPN transistor, and because I broke one of its legs removing it, I subbed in a BC549, one of the suggested alternatives in my transistor manual.

There were also sundry components, such as a 4-pin DIP-style opto-isolator, which was buried in varnish and bridged a physical channel cut into the board. I could only resistance-test this device, and it appeared to pass. There are also several series-connected thermistors, used as inrush current limiters, and a chunky metal-oxide varistor (MOV) used for surge protection; these all tested fine.

Having replaced the only parts I could find that could potentially be causing faults, all I could do now was to clean up where I'd been and re-coat the places I'd dug into the varnish with some standard polyurethane.

I doubt the board really needs it for

electrical protection, given it's all relatively low-voltage, and there would be no stray coronas developing on pointy solder joints. I'm assuming it is there in case metal dust or welding swarf might find their way into the cabinet and potentially short out something on the board.

In the end, I did as much as I could without testing the board in the welder, then sent it back to be reinstalled and tested in-situ. Theoretically, checking joints and testing individual components should resolve any problems, but we all know there is more to it than that, and it will only be dumb luck if the board works when put back into the machine.

More badly designed junk

Another potential Grot shop candidate is a USB3 hub I worked on recently. It had a problem that's common with many other modern devices. This hub was relatively new, but the socket inside had come away from the PCB, rendering it useless.

The owner wondered whether it could be repaired, not because it is a particularly expensive device, but because it irks him (as it does me) to throw something away that isn't that old or has had much use.

The problem with this, and other devices, is that it is designed to be small and portable, but the cable that comes with it is very heavy and not overly flexible, so the thing will never sit where it is placed, and the stress and strain on the socket is very high. The new USB-C connectors might solve these issues, but we shall see about that.

I'm sure this same problem affects all of us; my phone, which is a few years old now, is starting to show signs of socket wear, mainly because many of the OTG cables available now are quite heavy gauge, and unless I am careful, I can put a lot of strain on the charging socket. *Editor's note: this is one of the benefits of wireless charging; while slow and inefficient, it doesn't wear the USB connector!*

I also purchased a Raspberry Pi 4 a while ago, and this uses a USB-C connector for power and micro-HDMI for video output. Both these cables are so stiff that I just have the Pi sitting in mid-air, at whatever angle comes naturally with the cables plugged in. To do otherwise would probably rip the sockets off.

Given that these sockets usually rely on only a few tiny solder pads for adhesion, it's no wonder they come adrift, even with normal use.

Re-attaching the USB socket to the hub wasn't too taxing; the challenge was getting the thing apart without breaking the plastic clips they used to hold it together instead of screws (another Grot idea). I suggested the owner let the repaired hub hang naturally on the cable and hope it doesn't break again.

I wonder if someone has upset the designers of these devices, and they are exacting their revenge on society by designing shoddy, unserviceable products. If so, I wish they would take their frustrations out in some other manner, such as with a stress ball or a punching bag. Do us servicemen a favour, please!

HP8595 spectrum analyser repair

A.L.S., of Turramurra, NSW has been up to his usual hobby of buying cheap test instruments from internet sellers. And as is so often the case, they turned out to need a bit of TLC (by which we mean 'serious repairs') to get them back into full working condition...

You can buy a second-hand Hewlett-Packard HP8595E spectrum analyser quite cheaply on the internet. These devices can analyse signals from 9kHz to 6.5GHz, but they are starting to age a bit as they were new in the late 1980s. Many now have little gremlins growing inside them.

The HP85xx series was very popular 25 years ago, because these instruments are portable and easy to use. So there are thousands of them for sale, and many parts available on the internet.

The one I bought was a real find because it included several options, including the HP-IB/parallel port interface for external control and printing. It was this option which convinced me to buy the instrument, so that I could keep records of various traces.

Its specs are really impressive, and it analyses an incredible array of RF and modulated signals, including TV signals. It also has an FFT function to analyse harmonic distortion of AM/FM audio signals.

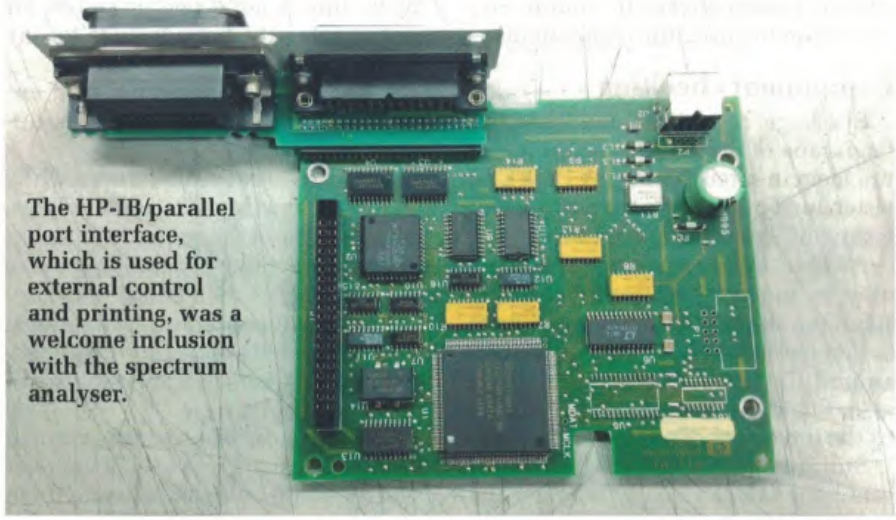
On receiving the device from the USA, I immediately tried out the print function and connected up my "Print Capture" device (parallel-to-USB module). This allows me to download screen grabs, and has worked tirelessly on all my test instruments with parallel ports. But it refused to work this time.

Another way I can obtain screen grabs is via a GPIB-to-USB adaptor, but that also failed to work. To my horror, no matter how many combinations and permutations I tried, I could not get any screen grabs out of the device!

Of course, you can photograph the trace on the screen easily, but the result is not as crisp and neat as a digital hardcopy, because the signal moves a bit and blurs.

An obvious clue as to why this was not working was that the option "041" was not listed on the setup screen. But the other three options that were supposedly installed according to the seller were listed there. So my immediate thought was that the board was installed, but not connected correctly, so it was not being detected or used.

The instrument is relatively easy to open up. I just had to unscrew four Allen-head bolts and four Philips-head screws. The cover then slides off.



The HP-IB/parallel port interface, which is used for external control and printing, was a welcome inclusion with the spectrum analyser.

The first thing I noticed after opening it up was that there were some missing screws, which suggested someone had previously been inside it. I feared that a dodgy board had been fitted just so that the instrument could be sold with more options.

However, once I got a chance to inspect it, I found that the GPIB board looked pretty good. It was a bit dusty, and I noticed that the multi-pin DIL connector looked a tiny bit crooked. I disconnected everything and applied some contact cleaner to the plug and socket. It was then that I noticed a bent pin on the male header.

I wasn't sure if I had bent it during the disassembly, as the plug was very stiff with age when I disconnected it (I guess we all end up that way!).

Anyway, after cleaning the board and connectors, I straightened the pin and plugged it back together. It snapped into place. On start-up, the option "041" appeared, and I was finally able to obtain beautiful hard copies via both parallel and GPIB. Sadly, though, that is not the end of the story!

The plot thickens

Some weeks later, I noticed that the analyser amplitude readings seemed a bit low. I connected its internal calibration signal up to the input and obtained a reading about 18dBm lower than expected. So I ran the "cal amplitude" routine.

To do this, you need to connect a BNC patch cable from the calibration output directly to the input and then press the "cal amplitude" soft-key. The instrument should be warmed up for at least 30 minutes before doing this. It takes several minutes, and during this time, you hear plenty of relays clicking in and out. However, in my case, it stopped after a minute, and a message came up saying "Cal gain: Fail".

The service manual explains that this means the signal was too weak and outside the specified minimum level. Either the calibration signal was poor, or there was an internal problem with the analyser.

The manual suggests checking the following parts of the circuit: A3 front end, A7 analogue interface, A9 third converter, A11 bandwidth filter, A12 amplitude control, A13 bandwidth filter and A14 log amplifier. That really narrows things down – not (consider that these assemblies total about half of the instrument)!

A beautiful 'hardcopy' finally emerged after fixing the improperly connected circuit board.

Hoping it was just the calibration signal at fault, I hooked up a 1GHz generator but found that the reading was still 18dBm low, proving that the problem was with the measurement side of the instrument. I was hoping it wasn't a front-end problem, because the attenuator is buried deep inside, whereas the other boards are merely plug-ins and changing them is an easy job, if time-consuming.

I did some internet research and discovered a great three-part YouTube video about fixing an HP8590, which is a similar device but with a 1.5GHz maximum frequency. I highly recommend it if you enjoy repair stories. See: https://youtu.be/kV4BOf3Oqk8

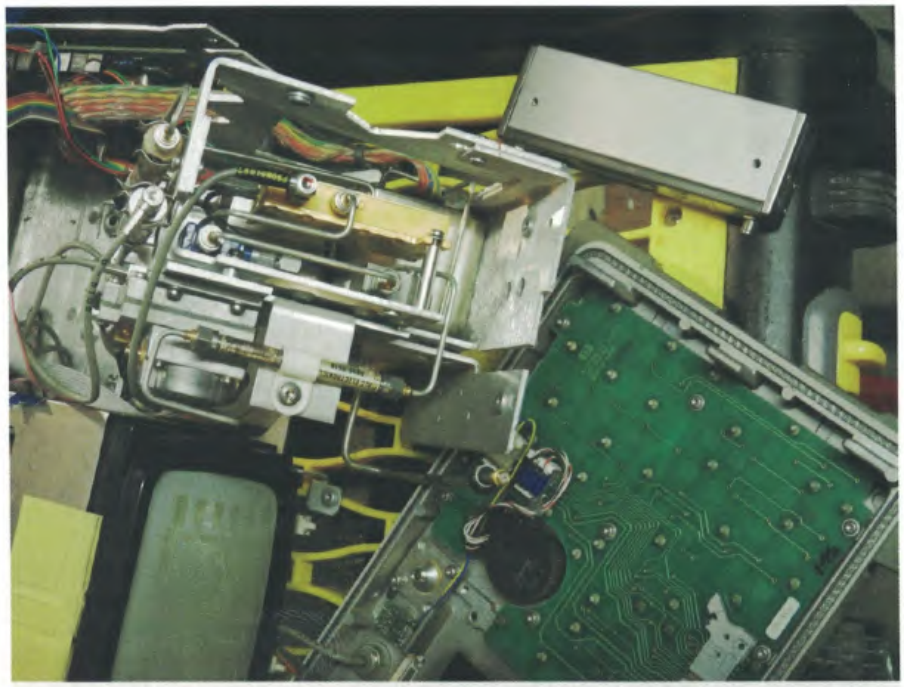
This inspired me to check out the symptoms of my instrument, and I noticed that when I manually adjusted the attenuation, I could get a correct reading when it was set to -20dBm.

But the readings were all over the place at other attenuation settings. I also got obscure readings at different frequencies; precisely the same symptom as in part three of those YouTube videos.

Unfortunately, this meant that the attenuator was the immediate suspect and so it would be a significant repair.

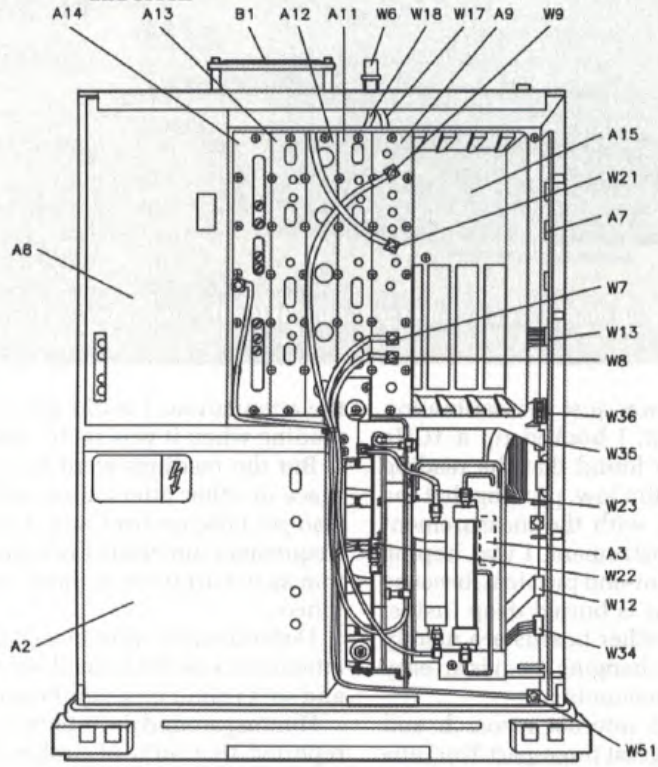
Hunting around the internet, experts reported that 90% of problems with these instruments were the result of poor or damaged attenuators, so I immediately looked around for a second-hand or reconditioned attenuator.

As luck would have it, I found somebody selling a brand new attenuator, all sealed up in its original HP box, so I made him an offer (which he didn't



The analyser's 'front end' which processes the input signal via the attenuator. The faulty attenuator (top right) was deep inside. It looks more like plumbing than electronics!

Figure 11-3 Instrument Top View 8592L, 8593E, 8594E, 8594L, 8594Q, 8595E, and 8596E



refuse), and the part arrived in a few days from Italy.

Now the fun and games began! The YouTube guy, who calls himself "FeedbackLoop" (siliconchip.com.au/link/ab3c), did not go into details of how to extract the attenuator. I could not even find it after searching for some time!

The diagram in the manual is somewhat simplified, and the assembly (labelled A3) is just shown as a dotted line. You cannot get to it from the side, so the whole aluminium assembly has to come out in one piece.

Everything looks pretty simple until you figure out how to extract it because it's a bit like a Rubik's cube. You have to start by loosening screws and then gently shaking things to discover how to extract the entire "box" containing the attenuator.

For fear of boring readers, I won't describe the exact procedure here. But if you find yourself in the same boat as I was, you may wish to write to SILICON CHIP so your message can be passed on to me. I will then reply in excruciating detail.

I think the money I spent to obtain a new attenuator just drove me on to replace the suspect one, despite the herculean task before me, because it would be such a waste to have a beautiful new part and never use it. Sort of like those blokes who buy an expensive car which then just sits in the garage, never being driven. What a waste!

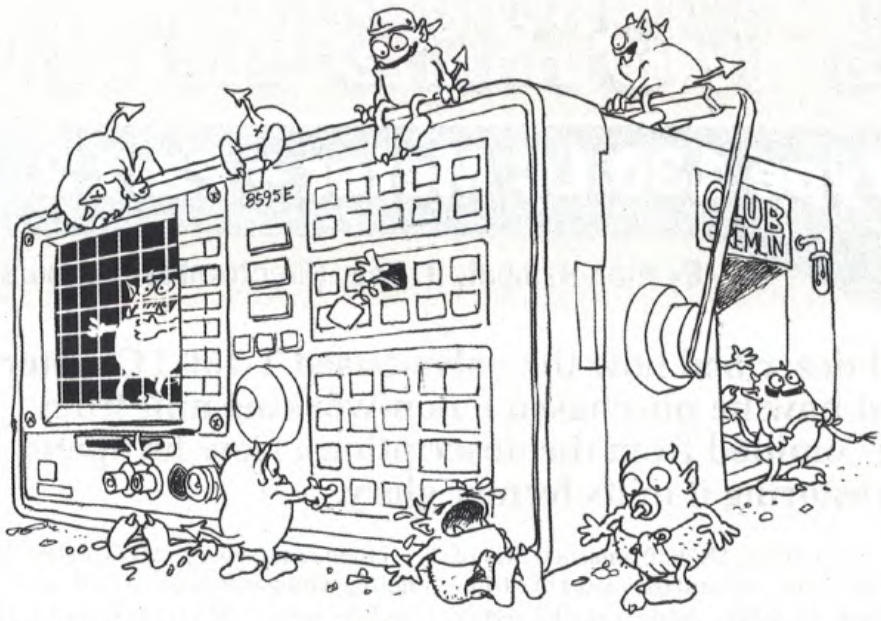
You will see in the picture here that the assembly looks somewhat like a UHT dairy plant and is more about plumbing than wiring, because of all the semi-solid cables which require disassembly. Caution is advised here, because they must not be bent. I had to work slowly and patiently to unthread some of the wiring harnesses between the semi-solid cables.

Finally, I managed to extract the culprit and replace it with the brand new part, but it required the same amount of patience to re-assemble everything. Naturally, I made some mistakes and had to do it all over again when I realised that I couldn't re-fit one of the retaining screws because an aluminium housing was blocking it. But finally, it was done, and I checked it all thoroughly in case something was amiss.

Very cautiously, I switched it on, hoping there would be no nasty noises. Amazingly, it all started fine, and the measurements were almost exact to within 0.5dBm. The frequencies were also spot on!

After celebrating for the required 30-minute warm-up, I performed a self-calibration, and the accuracy improved even more. I was really glad I purchased the brand new attenuator (at significant cost) because if it was a second-hand 'dud', it would have been a colossal waste of time and effort.

Now I have a really precise and importantly, working instrument. I intend to protect the attenuator by using a DC-blocking device and an external attenuator, in case a DC voltage might



MANY NOW HAVE LITTE GREMLINS GROWING INSIDE THEM

accidentally be applied. Any applied DC will destroy it, as will RF signals which exceed 1W or +30dbm.

3A USB charger repair

B. P., of Dundathu, Qld has had the same simple fault fell multiple devices in his possession. Is he cursed, or is this a case of bad designs multiplying? You be the judge...

When chatting with my mate via Skype on a Samsung Galaxy S 10.5 Tablet, I found that its battery would discharge even though the supplied 1A USB charger was plugged in.

I ordered a 2A charger on eBay, but I found that it was also unable to keep the battery at 100%, so then I purchased a 3A charger. This one was finally able to keep the battery charged at 100% while using Skype. As I was quite happy with it, I decided to get a spare, so I ordered another identical one.

The original 3A charger worked well for a couple of years, but recently I noticed that the battery was discharging even while it was plugged in. I felt the charger and it was cold, so it clearly wasn't working, as it was usually quite warm when in use. Swapping it for the spare charger got me back in business.

I decided to try to fix the failed unit. It appeared that the two halves of the case might be glued together, as is common with many chargers, so I clamped it lightly in the vice with padding, to see if it would crack open. It popped apart and I found that it wasn't glued, but instead clipped together. This was good news, as it would be much easier to reassemble it later.

I had a close look at the circuit board and noticed blue corrosion build-up on two of the 1N4007 diode leads, but these diodes and the other diodes on the board tested OK. I then noticed a 1Ω 0.5W resistor marked "F1" on the circuit board, indicating that it was used as a fuse. This resistor was connected between one of the mains wires and the rest of the circuit and when I tested it, it was open circuit.

I didn't have any 1Ω 0.5W resistors in my parts bin, only 1W types, but I managed to salvage a similar resistor that tested OK from another dead charger.

I reassembled the charger and tested it, and it worked just fine. However, after a few weeks of use, the charger failed again. I wasn't surprised when I opened it up and found that the same resistor was open circuit. I decided to replace it with a 1Ω 1W type, and it has been working reliably ever since.

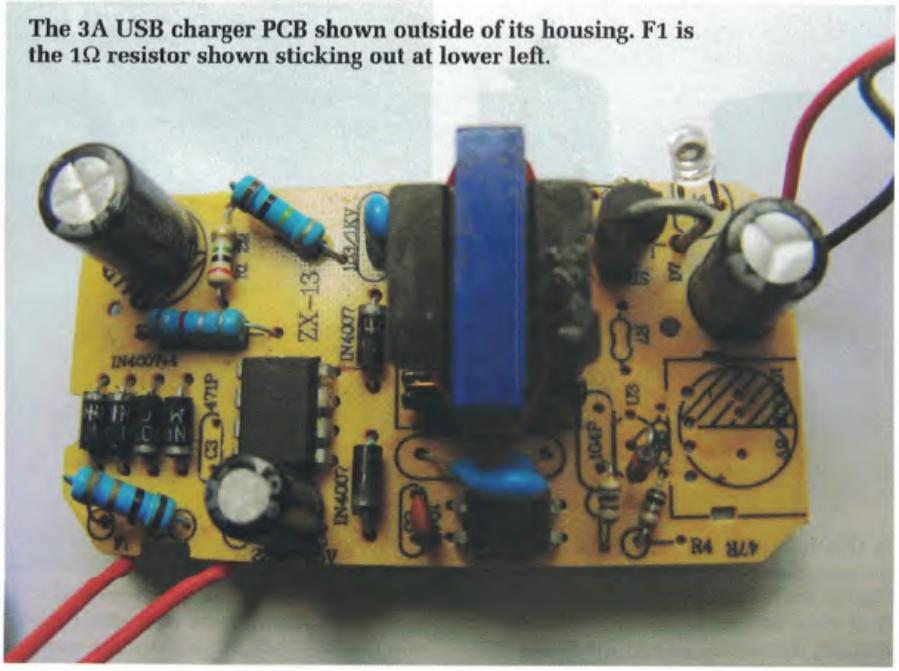
Even though this 3A charger only cost me about $5, it was an easy fix which not only saved me $5 and the wait for a new one, but that was one less device going into landfill.

I had a similar problem with the sensor light on our front verandah. Its 'fuse' resistor failed several times, so I ended up replacing it with two higher-rated resistors in series. That repair then lasted the life of the sensor, which eventually disintegrated due to UV deterioration of the plastic.

I've also had mates bring me other USB devices which had stopped working, and I was able to fix those by, you guessed it, replacing a fusible resistor.

So this is a very common configuration in devices where a low voltage is derived from the mains, and failures of this part are a common occurrence. It's likely that the resistors are just barely rated for their use in this configuration, so it may be necessary to increase the rating of the resistor to compensate for the inadequacy of the original resistor to cope with higher ambient temperatures and high mains voltages. SC

The 3A USB charger PCB shown outside of its housing. F1 is the 1Ω resistor shown sticking out at lower left.



VINTAGE WORKBENCH

The Tektronix Type 130 LC Meter – Part 2

Restoration

By Alan Hampel, B. Eng. (Electronics, Honours)

Last month, Alan Hampel described how the valve-based T-130 LC meter worked. He also described how he purchased a non-working unit from eBay (with "non-working" omitted from the description). Now he opens it up and starts work on restoring it to its former glory.

I unwrapped the package from the eBay seller and took the T-130 cabinet sides off. It was covered inside and out with cigarette smoke gunk. That's not uncommon in old laboratory instruments. Instead of the cabinet being an attractive blue, it was a dull blue-grey.

The cause of the clunking noises was immediately apparent – there was no 6X4 in the rectifier socket, but a 1N2630 solid-state valve replacement rectifier was loose amongst the works.

The 1N2630 was no doubt put in the 6X4 socket by a previous owner. But it's about four times as heavy as the original valve, being solid epoxy and not mostly vacuum. It also has a larger diameter, fouling the socket retaining screws and preventing the socket fully gripping the pins; so it fell out.

The loose 1N2630 smashed one of the 6U8s and bent the plates of a trimmer capacitor. Annoying, but easily fixed. I also noticed the meter clear plastic casing was broken in one corner – the only corner not shown in the eBay photos.

Preliminary evaluation

I carefully straightened out the bent trimmer capacitor plates and performed a thorough search for glass fragments within the instrument and in the packaging. I only found two tiny pieces jammed in out-of-the-way spots, but not anywhere near enough to account for the smashed 6U8. So someone cleaned out almost all the glass before shipping, without replacing the smashed valve. Interesting.

A 1N2630 (left) was used instead of the original 6X4 (right) as the rectifier. Due to its larger diameter and weight, it came loose from the socket in transit, damaging one of the 6U8s.

The front panel glass was cracked along one edge. There was also grime and dirt inside and outside the case.

I then removed all valves, carefully noting which valves came from which sockets. It's a good idea to keep valves separate, even if they are the same type, especially if they are double-valves like 6U8 triode-pentodes and 6BQ7 twin triodes.

Such valves, when faulty, have a high probability of producing entirely different symptoms or no symptoms at all depending on which socket they are plugged into. Nor do you want to allow circuit faults to cause any more damage than has already occurred.

The T-130 came from the USA, so the next thing I did was to rewire the power transformer twin primaries for "234VAC" operation, and I also changed the fuse to one half the original amperage.

The seller supplied a power cord, with the correct US NEMA 3-pin female on the instrument end, and a standard US 3-pin male plug on the other end. That's no good in Australia, and it was a very short cord too, so I bought a longer NEMA power cord on eBay and changed the male end to an Australian 3-pin plug.

I then plugged the instrument into a Variac and slowly wound it up from 0V. Nothing dramatic happened (no smoke released), but when I got it up to 200V AC, I noticed that the front panel pilot light was still not lit. The lamp socket pins were bent and shorting out the heater wiring. More damage from the loose 1N2630, most likely.

I lengthened the short circuit and tried again with the full 230V AC mains. The secondary voltages on the power transformer were correct, so I

If you have a Tektronix instrument with this AC mains connector on the back, check the Earth pin. It may show high resistance due to a loose retaining nut.

plugged in a 6X4 taken from an old radio, and the 0B2 regulator. I knew the 6X4 was pretty weak, but the HT drain in the T-130 should be a lot less than a typical radio, and I needed to quickly work out what was what before contacting the seller.

I now had 260V and 149.5V on the HT rails, and 75V DC on the heater wiring, so things were looking good.

As the 6U8 in the V30 socket had been smashed, I plugged in a 6U8 taken from an ancient TV, checking that the heater wiring was still at +75V in case there was heater-cathode leakage. It was still good, and my CRO showed oscillation at about 140kHz.

Next, I plugged in V4, another 6U8, functioning as the variable oscillator. I was rewarded with weak oscillation on the CRO at about 140kHz, varying with the position of the front panel COARSE ZERO control. The heaters still measured +75V DC, so no major faults were apparent.

I proceeded to replace the remaining valves one at a time, checking the +75V rail each time, and was rewarded with front panel meter deflection, varying with the COARSE ZERO control. Now I knew there was nothing major wrong, so I probably wouldn't need any parts made from unobtainium to fix the set (eg, transformers or coils). I therefore decided to proceed with a full clean and restoration.

To conduct further tests, I connected a 415pF tuning capacitor to the UNKNOWN socket, set the capacitor to minimum, and adjusted the COARSE ZERO and FINE ZERO controls for a zero reading on the 0-300pF range. Slowly turning the tuning capacitor towards maximum, I noticed two things:

1) The meter reading increased from zero up about 80pF indicated, then slowly decreased back to zero at about 120pF from the test capacitor! I thought this might be a problem with the Schmitt trigger circuit, perhaps the 6U8 (V70).

2) As the tuning capacitor was turned, there were violent swings of the meter (and I do mean violent!) at certain settings. The CRO showed this was due to the Schmitt trigger breaking into RF oscillation.

Schmitt trigger circuits can sometimes oscillate if the valve is weak, or a resistor has gone high, usually because the positive feedback is insufficient to produce a definite snap action, but enough to oscillate with reactances present in the circuit.

14 rules of restoration

I follow 14 rules when repairing or restoring vintage professional electronics. I learnt these rules when I was employed servicing professional electronics at the tail end of the valve era. The rules maximise reliability and preserve resale value.

1) Never unsolder any component until, by deduction or in-circuit testing, you have proved that it is faulty.

2) Never put back any part that you unsoldered. Replace it with a new one (or NOS/NIB if a new part is unavailable).

3) Never replace non-electrolytic capacitors just because they are old and might be leaky. In professional equipment, leakage is a lot less likely as higher grade parts are used, voltages are lower, temperatures are lower than in typical valve radios, and circuits are more tolerant.

4) Never replace electrolytics just because they are old. The long-life types used in professional equipment are often perfectly good; there's no sense in sacrificing the factory look if there's nothing wrong with it.

5) Never swap valves of the same type around in the chassis as a diagnostic strategy or to fix a fault. Each valve stays where it is unless and until it is proved defective, at which point it is replaced with a new valve (these days, a NOS/NIB valve).

6) Clean and touch-up paint before addressing faults. Cleaning does sometimes cause more faults, and a nice clean instrument is a pleasure to work on.

7) After cleaning, check every single resistor for correct resistance (without unsoldering it) and every electrolytic in-circuit before proceeding with any diagnostic procedure. But don't replace anything found faulty yet.

8) Don't rely on an overall functional check or rely on a check against performance specifications. Go through each stage with a scope and verify that each stage works precisely as it should. Replace parts identified as out of specification as you go through each stage.

9) Some brands of capacitor are known to fail sooner or later. Replace these after each stage is verified good and the instrument meets and exceeds specifications. My T-130 did not have any such components.

10) Every single time you replace a component, do a comprehensive set of checks to verify both that the fault due to that component has been cleared, and that no new symptoms have appeared.

11) Where possible, replace resistors and capacitors with the same original type, or if you cannot obtain originals, use comparable components of the same vintage.

12) Clean and lubricate all switches, pots, variable capacitors and (later, during alignment/adjustment) presets. Don't just apply contact cleaner/lubricant to switch wafers and pots, do variable capacitors as well. Make sure you apply grease to wafer switch clicker mechanisms.

13) Never touch calibration adjustments or presets until there is nothing else left to do or check. Mostly, you'll find that an apparent need for adjustment (beyond minor touch-up) is in fact due to a faulty component.

14) Do not modify to fix a fault. Resist the temptation to modify to improve performance. Reputable manufacturers knew what they were doing.

Tektronix component strips and soldering

Tektronix installed pig-tail type resistors, capacitors, and other small parts on ceramic terminal strips (see photo below).

These strips have a glazed finish; they look nice and are rigid, which helps stable circuit operation and reduces vibration-induced failures. They also have negligible leakage and RF loss, and do not grow fungus in high humidity climates like phenolic tag strips can.

The strips also come in two different types, one that used nuts and bolts on the underside for mounting and the ones used here have snap-in fittings. The former was used in earlier models and could help determine the age of the meter.

Many people think these ceramic strips are unique to Tektronix, but a limited number of US manufacturers used them in tube-based military equipment. The Japanese test equipment manufacturer Meguro used similar ceramic strips.

Tektronix made these strips by coating the moulded but unfired strips with a paste of silver particles dispersed in an organic grease, then wiping the excess off. The wiping leaves the paste neatly confined within notches and slight depressions surrounding each notch.

Upon firing, the grease evaporated, leaving a microscopically thin coating of silver in and around each notch, bonded to the ceramic. They then tinned each notch ready for soldering in the components.

The downside of these strips is that silver readily dissolves in ordinary tin/lead solder, and solder does not stick to ceramic. Hence, using normal tin/lead solder will weaken the silver-ceramic bond and will, sooner or later, cause it to fail completely. In the factory, Tektronix used a tin/lead solder containing 3% silver, the 3% being sufficient to stop its affinity for more silver completely.

62% tin, 35% lead and 3% silver solder used to be available from Tektronix under part number 251-514, but they ceased selling it many years ago. Its melting point is 188°C.

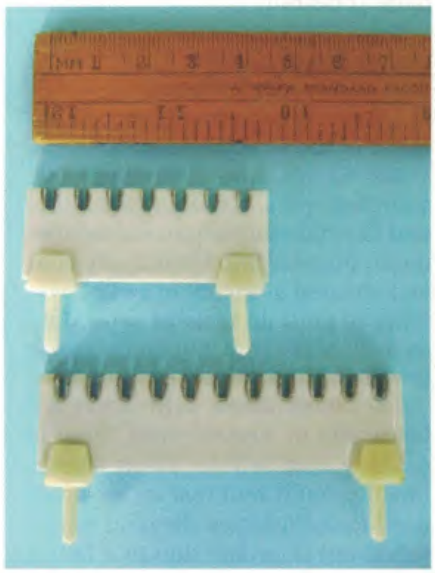
Note that this isn't "silver solder", which is a British term for brazing alloy. Nor is it modern lead-free electronic grade solder, which contains silver but has a significantly higher melting point that can damage the ceramic strips.

Tektronix usually installed a small roll of silver loaded solder inside their oscilloscopes. They often did not include it in cheaper instruments. If you have a Tektronix instrument that does not have the little roll, it's either because someone has swiped it, Tektronix never included it, or you have an instrument originally supplied to the military.

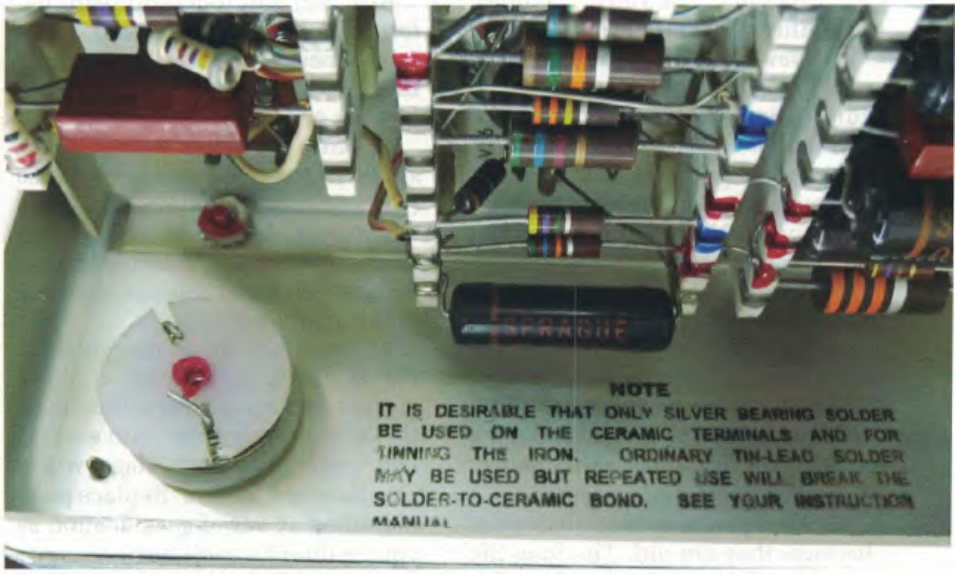
Fortunately, solder containing 62% tin, 36% lead, and 2% silver is readily available from RS Components (Cat 271-4172), along with element14 and other distributors.

When working on Tektronix ceramic strips, if you don't have the supplied roll, **always** use the modern 2% solder. Even 2% silver solder isn't optimal, and you probably don't know the history of the device, so you must assume the strips have already been weakened. New strips do occasionally show up on eBay, but only occasionally.

Never place the soldering iron tip within a notch and apply any force. The ceramic easily cracks if you do. Use a temperature-regulated chisel tip 5-6 mm wide and apply it to the side of the notch.



Two of the ceramic terminal strips, which many of the components mount on. The notches in this strip are lined with a silver alloy and the strip can be mounted via snap-in fittings (as shown) or bolt-on depending on type.


NOTE
IT IS DESIRABLE THAT ONLY SILVER BEARING SOLDER
BE USED ON THE CERAMIC TERMINALS AND FOR
TINNING THE IRON. ORDINARY TIN-LEAD SOLDER
MAY BE USED BUT REPEATED USE WILL BREAK THE
SOLDER-TO-CERAMIC BOND. SEE YOUR INSTRUCTION

An example of the ceramic strips in place within the left-side of the chassis with components soldered in. You can also see a warning about only using "silver bearing" solder as tin-lead solder will eventually damage the silver alloy on the strips. The T-130 did not come with this solder, so I turned a replica reel (shown to the left of the note) and added 2% silver solder from RS Components. There is more detail on these strips and the recommended solder in the panel above.

I also noticed that the zero setting wandered about, and could not be brought to an actual zero beat, so that on the lowest range (3pF full scale), the meter had over full-scale deflection regardless of the COARSE ZERO control setting.

Contacting the seller

I sent a message to the seller via eBay, informing him that the instrument was not operational, thus not conforming to his description, and I explained why.

He promptly wrote back, apologising, and offering to send me two replacement NOS/NIB (new old stock/new in box) valves: a 6X4 and 6U8. I accepted that, but pointed out that the instrument uses five 6U8s and at least one more was probably faulty.

The seller then arranged for a US surplus valve dealer to courier one 6X4 and three 6U8s. They arrived two days later. They were mil-spec valves (W-suffix) too. I certainly couldn't complain about the after-sales service.

Making it pretty

Cleaning the cigarette smoke condensation off the cabinet was easy. I removed all cabinet parts from the central chassis and washed them, along with the front panel knobs. I did this in the sink with dishwashing detergent.

I used a soft sponge to clean the cabinet parts and a toothbrush for the knobs. I then thoroughly rinsed everything with running water and then Electrolube Saferinse, and dried the parts off. Everything came up like new, except for a few places where the paint had been worn off over the years.

"Tek Blue" touch-up paint used to be available from Tektronix under part number 252-0092-02, but not any more. Googling, I discovered that this paint was made by the Chemtron Aerosol division of Rudd Company Seattle. They no longer exist.

So instead, I bought the following from Bunnings: White Knight Rust Guard Quick Dry Advanced Enamel, Neutral Tint Base 500mL Stain Finish, colour coordinates W 36.5 B 16.5 D 27 E 16.

This gives an excellent match. 500mL is far more than I could ever use for touching up Tektronix instruments, but is the minimum they let me buy. I used a cotton bud to apply the paint where needed on the T-130 parts.

The UNKNOWN connector on the front panel is an old-fashioned UHF (SO-259) silver-plated socket, common on test gear made before the 1960s. It is much better than a BNC type in this application – a BNC connector does not have the mechanical strength to support accessories typically used with the T-130.

The connector was badly tarnished and missing many of its 'teeth', so I replaced it with a new one. Next, I reassembled the instrument using new screws, because the old ones were all corroded and unsightly. Shiny new screws make all the difference – the instrument now looked brand new – on the outside, anyway.

As with many electronics manufacturers in the 1950s and '60s, Tektronix painted internal cabinet and chassis screws and adjustments with what Tektronix staff called "Red Glyptal". Glyptal is a USA-based specialty paint manufacturer. The original formulation is no longer available, at least in small quantities.

Replicating Red Glyptal on the screws and adjustments is a nice touch in restoration. Many restorers use nail varnish, but it's far from ideal, in appearance or mechanical strength. A close equivalent is "BLR Tamper Proof Seal", available from RS Components (Cat 196-5245).

Estimating the age of a T-130

This can be difficult, as the T-130 was manufactured for 21 years, and there are no date codes on any of the parts, except the valves.

Of course, valve codes are useless, because you don't know what valves have been replaced during the instrument's life, and you don't know if any replaced valve was new, NOS, or merely an old valve somebody had on hand, good or otherwise.

You also can't rely on the serial number, at least not directly, as it is not known how many were sold in any given year, and that can vary widely. For an instrument like the T-130, which filled a niche need for the first time, there were probably brisk sales in early years, and then just a trickle each year, as new laboratories and factories started up.

For oscilloscopes, Tektronix used a few different coding schemes. These encoded the factory which produced the unit, country of origin, the revision level, and in some cases the date of manufacture. But it appears no coding scheme was used for the T-130, and the serial numbers were purely sequential.

In some cases, the serial number for smaller Tektronix instruments was sequential to the production line output, not to the instrument type.

For example, a production line may have been making a batch of T-130s and then changed over to making T-123s (an oscilloscope preamplifier). If the last T-130 in the batch was given serial number 00226, the first T-123 would receive serial number 00227.

Thus, some smaller Tektronix instruments had large gaps in their serial number ranges. This likely applies to the T-130, as the number sold would not justify a dedicated production line.

Any Tektronix instrument with a serial number comprising a single letter and two digits is a pre-production sample or a laboratory prototype. Once in a while, these show up on eBay.

T-130 production started with serial number 101. The T-130 got a major facelift in 1958 (serial numbers 5000 and up) and a change in meter in 1965 (serial numbers 6168 and up).

If a T-130 has Sprague Black Beauty 160P capacitors (tubular capacitors with red printing), it was made 1960 or later. If it has Sprague Bumble Bee capacitors (colour-coded), it was probably made in 1960 or earlier.

Sprague "Bumble Bee" capacitors (left) mean the T-130 was likely made pre 1960, while "Black Beauty" 160P caps (right) indicate post 1960. The Bumble Bee caps usually leak, although leakage will often not affect the T-130's operation.

TYPE 130 L,C METER

Direct-Reading Inductance and Capacitance Meter

APPLICATIONS

Saves engineering time in circuit development work by providing quick inductance and capacitance readings even while circuit changes are being made. Aids in correct placement of critical components and leads.

Guard circuit produces a voltage of the same amplitude and phase as the voltage at the UNKNOWN terminals, but isolated from the frequency determining portions of the rest of the circuit. This permits separation of the capacitance to be measured from other capacitances and strays. Accurate measurements of direct interelectrode capacitance in vacuum tubes can be made with ease.

The Type 130 can also be used for component testing, sorting, and color code checking on a production basis.

GENERAL DESCRIPTION

The unknown value to be measured will determine the frequency of the variable oscillator in the Type 130. This frequency is beat against a 140-kc fixed oscillator. The difference frequency is shaped and counted, causing meter deflection proportional to the difference frequency. The direct-reading meter is calibrated in microhenries and micromicrofarads.

Guard Voltage

Permits measuring an unknown capacitance while eliminating the effects of other capacitances from the measurements.

Five Ranges

Microhenries—0 to 3, 10, 30, 100, 300.
Micromicrofarads—0 to 3, 10, 30, 100, 300.

Accuracy

Within 3% of full scale.

Coarse and Fine Zero Adjust

Four-Inch Illuminated Meter

VACUUM TUBE COMPLEMENT

Fixed Oscillator	6U8
Buffer Amplifier	6U8
Variable Oscillator	6U8
Buffer Amplifier	6U8
Mixer	6BE6
Bistable Multivibrator	6U8
Guard Circuit Cathode Follower	6BH6
CF Clamp and Diode Clamp	6BQ7A
Rectifier	6X4
Voltage Regulator	OA2

OTHER CHARACTERISTICS

Size—5" wide, 9" high, 8½" deep.

Weight—9 lbs.

Construction—aluminum alloy.

Finish—photo-etched anodized panel, baked gray wrinkle cabinet.

Power requirements—117/234 volts, 50-60 cycles, 40 watts.

Price **$195**

Includes: 1—P93C Probe
1—W130R Lead
1—W130B Lead
1—Instruction Manual

Recommended Additional Accessories

Type F30 Production Test Fixture. Speeds sorting and testing of capacitors and inductors $3.00

Type S30 Delta Standards, for calibration of Type 130 L,C Meters $22.00

Prices f.o.b. Portland (Beaverton), Oregon.

Here is a page from the 1954 Tektronix catalog; when they started to produce the T-130 LC Meter.
Source: *http://w140.com/tekwiki/wiki/Tektronix_Catalogs*

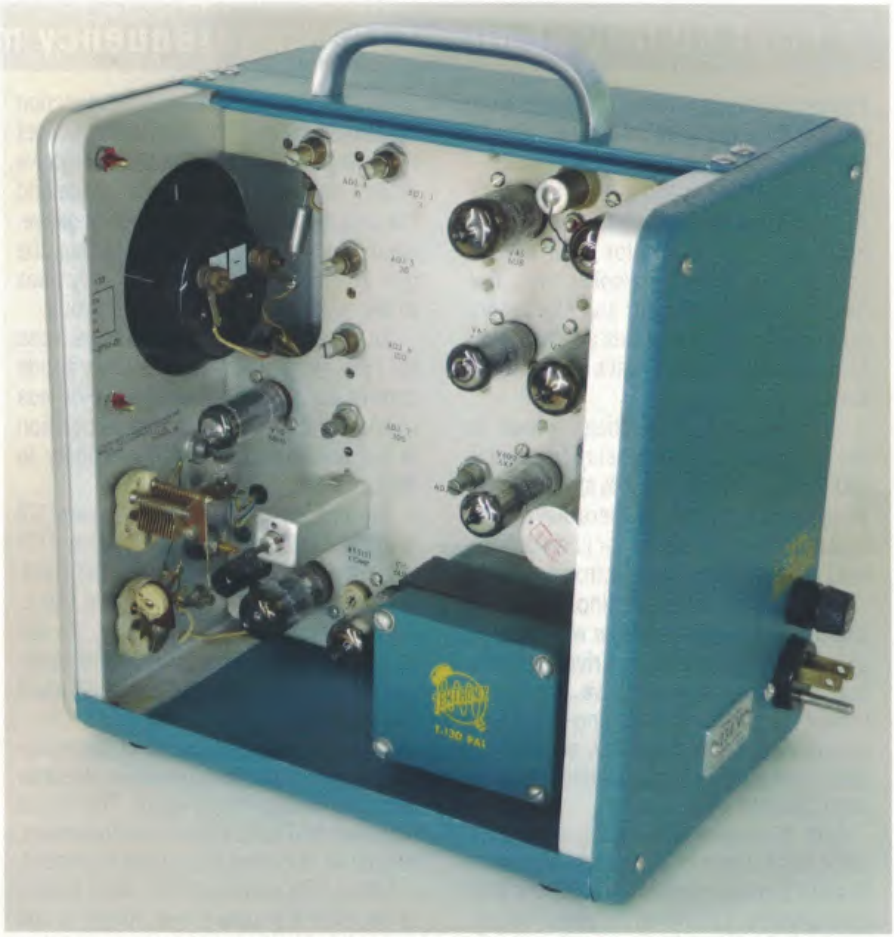
Safety hazards

I plugged in the power cord and checked the resistance from the Earth pin of the Australian plug to the T-130 chassis. High Earth lead resistance is a common fault in Tektronix instruments using a protruding NEMA 5-15 mains input connector. If you have one, best check it. Mine had an open-circuit Earth.

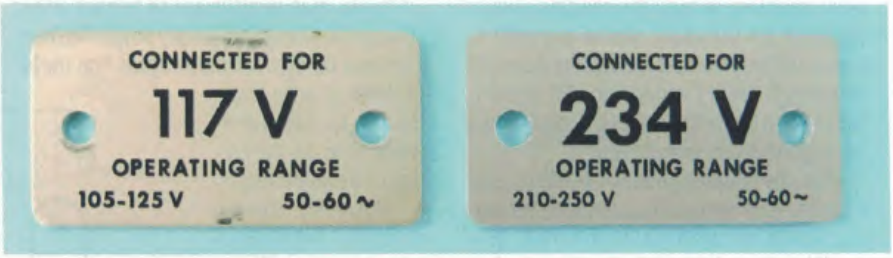
As is typical, the nut that secures the Earth pin to the connector backplate had worked loose. This is why you shouldn't use a mounting screw for an Earth connection, which isn't permitted by most authorities. There was tarnish on the Earth pin as well. I cleaned the pin and tightened the nut, using a drop of thread locker. I checked again with an ohmmeter – no perceptible resistance – good.

There is another safety hazard in the T-130. The range switch is a custom-assembled "Oak"-style three-wafer switch. The rear-most wafer selects the range setting capacitors and acts as the power switch on the primary side of the power transformer. So 230V AC is within a millimetre of the range selection common.

That's not very nice, Mr Moulton. It's an electric shock risk. One slip of a probe and the switch is history. And you can't buy a replacement now. I made a mental note never to probe with a voltmeter or CRO around the wafer while the T-130 is plugged in.



On the rear of the T-130 is the fuse, AC input and badge showing the voltage. A desktop NC milling machine was used to make a 234V AC badge to replace the 117V AC version shown below.



Internal cleaning

An internal clean was needed to get rid of accumulated cigarette smoke residue and the general dirt that accumulates in all valve equipment cooled by simple ventilation holes in the cabinet.

First, I washed the chassis, components and terminal strips with Safewash citrus solvent, applying it with a toothbrush and cotton buds.

Then, I went over it all again with Saferinse to get rid of the Safewash, and then again with isopropyl alcohol to remove the Saferinse. I was very careful to avoid getting any Safewash or Saferinse in the oscillator coils.

It is essential with old Tek equipment to thoroughly clean the terminal strips back to an uncontaminated glazed ceramic surface.

If you don't, the cigarette smoke residue and general grime will in time cause electrical leakage, if it hasn't already.

After cleaning, I took some photographs. Reviewing the photos, I realised the terminal strips still were not completely clean. So I repeated the whole process over again.

The T-130 was designed before high-grade polyester capacitors became available, but almost all T-130s, including mine, were made with professional-grade Sprague "Black Beauty" 160P capacitors (black tubular capacitors with red printing).

These seldom show any leakage. T-130s made before 160P production started in 1960 have Sprague "Bumble Bee" (colour-coded) capacitors, which usually do leak.

But quite a high leakage in the range capacitors (C90-C94), say 5µA, will only result in a slight change in FSD, which can be adjusted out in calibration. 5µA leakage in a radio grid coupling capacitor would have a disastrous effect on audio quality.

The only other tubular capacitor in the T-130 bypasses the 150V rail – leakage short of a definite fault there will have no effect.

Next month

Now that the T-130 was clean and safe, I could get into the nitty-gritty of figuring out what was wrong, fixing it, and then adjusting it back to its original factory-spec condition. But that will be in next month's article.

A brief history of direct-reading frequency meters

Digital frequency meters (counters) were not widely used until integrated circuits reduced the cost in the 1970s.

Imagine even a three-digit frequency counter implemented with valves. You'd need four twin valves for each decade counter, four for each display latch, five for each display decoder and eight more for time-base division. Plus another three for the power supply. That's a total of 50 valves!

But there has always been a need in design laboratories to measure frequency, and an analog meter of 1-5% accuracy was often good enough. So there have been analog frequency meters for just about as long as there has been electronics.

The earliest direct-reading frequency meters were just an amplifier with enough gain so that it is well over-driven, and the output is almost a square wave. The output is fed to a rectifier and moving-coil meter circuit via a small capacitor, so that the meter just gets a series of narrow pulses, one pulse per input cycle.

Due to mechanical inertia, the meter responds to the average current, so its deflection is proportional to frequency. This arrangement is shown in the upper circuit.

But this circuit has some serious disadvantages: if the input level is not sufficient to overdrive the amplifier, you get a low reading. In fact, the reading always depends on the input signal strength to some extent. The calibration also depends on not just the HT voltage and R1 and C1, but also on the emission of V2, even when V2 is completely overdriven.

Plus the contact potential of V3 causes a continuous deflection even with no signal. The pulse-width set by C1 must be a small fraction of the cycle time; otherwise, C1 will not discharge adequately, and the meter deflection will become excessive.

Howard Vollum, when a student at Reed College in 1936, wrote a thesis, "A stable beat frequency oscillator equipped with a direct reading frequency meter." The oscillator part was nothing remarkable, but his frequency meter significantly advanced the art. This is shown in the second circuit below.

Now V1 does not have to be overdriven. It can be an ordinary low-μ triode as its role is to provide a low-impedance drive to the transformer; this lowers its cut-off frequency.

The transformer provides push-pull drive to V2 and V3. V2 and V3 are small thyratrons and the circuit functions as a bistable (flip-flop).

Thyratrons (gas-filled triodes) function something like an SCR in series with a zener diode. If the grid is held sufficiently negative (-10V), no current flows in the anode and the grid. If the grid is taken less negative, anode current flow starts and ionises the gas. The anode current immediately rises to the maximum possible in the circuit.

The anode-cathode voltage stays close to 16V, regardless of what the anode current is. The grid is now more-or-less shorted to the cathode due to its position in the electron stream and proximity to the cathode.

Assume V3 is conducting (on) and V2 is off. The cathode of V3 is at 74V and C1 is charged to 74V, positive on the right. As soon as the left-hand end of the transformer goes sufficiently positive, V2 will snap on. V2's cathode rises immediately to +74V, so the right-hand end of C1 must rise to +148V, cutting off V3.

When the right-hand end of the transformer goes sufficiently positive, V3 turns back on, forcing V2 off again. The circuit flips back and forth at the input frequency, as long as sufficient input level is present.

C2 and C3 communicate short pulses to V4, which supplies two pulses to the meter for each input cycle.

So the output pulse amplitude and width is entirely independent of the input level. If the level is insufficient to trigger either thyratron, the action simply stops. As there are two pulses per input cycle, the meter pointer is a lot less likely to shudder with low (≲20Hz) input frequencies.

However, transformers were expensive, and Thyratrons cost more than hard vacuum triodes, yet were a lot less reliable and shorter-lived.

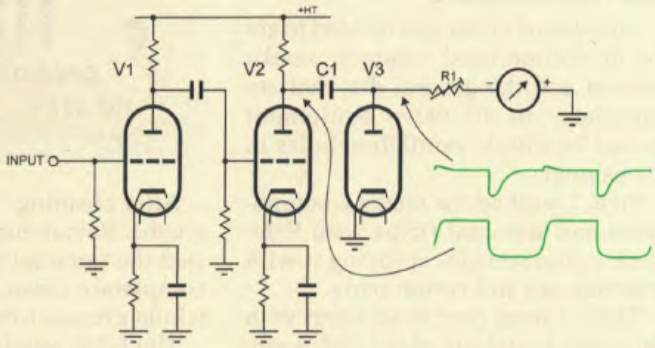
The next major advance came in 1941. National Cash Register Co. filed a patent (inventor L. A. DeRosa) disclosing a precision direct-reading frequency meter employing a flip-flop circuit based on two pentodes, triggered by an overdriven pentode amp.

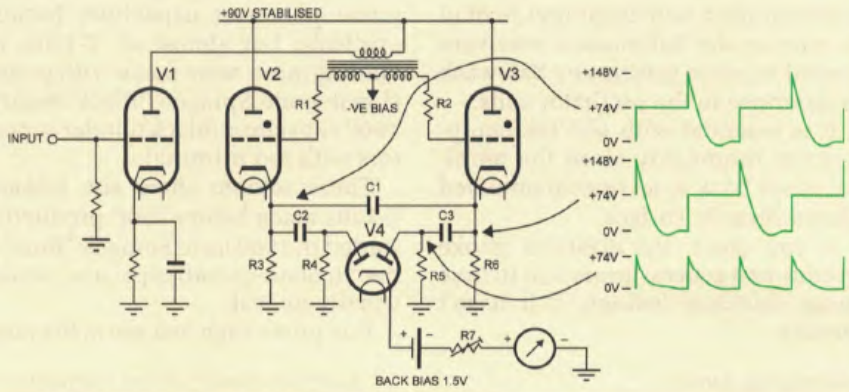
The flip-flop ran at half the input signal frequency, but two pentode monostable circuits were triggered from each flip-flop pentode. The meter then received one clean and square monostable pulse for each input cycle. It was a little more accurate, a lot more complex but not much more expensive than the Vollum circuit. It retained the correct-or-nothing reading operation.

In 1951, Howard Vollum was now Tektronix chief engineer, and new engineer Chris Moulton was designing the new 'bistable' configuration used in the T-130. With the amplitude clamp circuit added by Moulton, his circuit is a lot simpler than the DeRosa method and just as accurate.

Most, if not all, subsequent designs for audio direct-reading frequency meters are derivatives of the Moulton and/or DeRosa methods.

The Hewlett Packard 500B/C Frequency Meter/Tachometer used a Schmitt trigger followed by a monostable briefly turning on (once per cycle), with a constant current source feeding the moving coil meter. With a rectangular or on/off pulse instead of a capacitor decay, the need to keep the pulse width small compared to one cycle is removed. **SC**





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Infrared Remote Control Assistant

Remote controls are handy, but sometimes equipment makes their use quite clunky. Selecting between live TV, DVD/Blu-ray, pay-TV and internet streaming on a television often requires you to press several different buttons in sequence. Now, these sequences can be performed at the press of a single button using the Infrared Remote Control Assistant.

By John Clarke

It's even more annoying when the multiple steps require the use of more than one remote control.

If you have several sources connected to your TV, you may need to open the 'source' menu and use the up or down or left and right buttons on its remote control to select the source and then press 'Enter' to select that input.

There can be even more presses involved to access internet streaming such as from SBS On Demand and ABC iview.

This *may* be OK for you (you probably set the TV up!), but your spouse, parents and friends probably don't appreciate the complexity, and may well not be able to figure out how to do this.

The IR Remote Control Assistant helps solve this. It vastly simplifies the procedures by recording the sequence and then replaying it whenever a button is pressed.

It isn't useful just for these complex remote control sequences either. It can also perform the same task as a single button press on multiple remotes, so you can perform common tasks without having to go to the device's specific remote control.

For example, you might want to set up the IR Remote Control Assistant to provide volume control as well as handling complex sequences.

What about learning remotes?

Many universal remote controls have a learning function, but they are designed to provide a single function for each button switch. They can't store a long sequence of infrared codes.

With the IR Remote Control Assistant, there are eight push button switches and each can be used to store separate infrared remote control sequence procedures in memory. It not only stores the codes required in the right sequence, but also the delay between each button press.

This may be important as some sequences require you to wait until the device is ready to proceed with more button presses.

It can typically store up to 100 separate remote control codes in each sequence (ie, up to 800 codes total). Sequences can run for up to about two and a half minutes, although the total time may be reduced if there are many complex codes involved.

For example, for ten typical button presses, the maximum sequence time is two minutes and 36 seconds but for 50, it drops to about one minute and 20 seconds.

In practice, you're unlikely to require a code sequence so long in either number of codes or time duration that you run out of memory. And the unit can record eight separate sequences; each is allocated its own memory space.

Presentation

The IR Remote Control Assistant is housed in a remote control case that has a separate battery compartment. The eight sequence pushbuttons are on top, while at the front is the infrared (IR) LED that sends the codes to the TV or other device.

There is also an IR receiver used to receive the infrared codes for recording sequences.

A small switch is included to select between the record or play mode, while a visible-light LED indicates operation.

The IR Remote Control Assistant is easy to use. Once it has been programmed, just press one of the eight pushbuttons to replay a stored IR sequence. The LED indicator flashes in response to the code being sent. While the IR Remote Control Assistant is playing back an infrared sequence, it can be stopped by pressing any button.

Programming sequences is also quite easy; this is described below, after the construction section.

Circuit description

The full circuit is shown in Fig.1. It's based around 8-bit microcontroller IC1, which is the electronic 'brains' behind the IR Remote Control Assistant. While we've often used the PIC16F88 in the past, that part is now no longer recom-

Features & specifications

- Deep memory storage
- 666.66ns sampling resolution
- Eight separate independent selections available
- Up to 100 separate IR code storage possible per procedure
- 174s (2m 54s) maximum record time per procedure
- 34.4kHz to 41.66kHz modulation adjustment range, in 15 steps
- Easy learning or record function
- Automatic memory erase before recording on each selection
- Bulk erase of all eight selections available
- Indicator LED
- Adjustable infrared modulation frequency
- Battery powered, with low standby current (3.3µA typical)

mended for new designs and is becoming more expensive. The PIC16F1459 has a lot more features but despite that, it is cheaper.

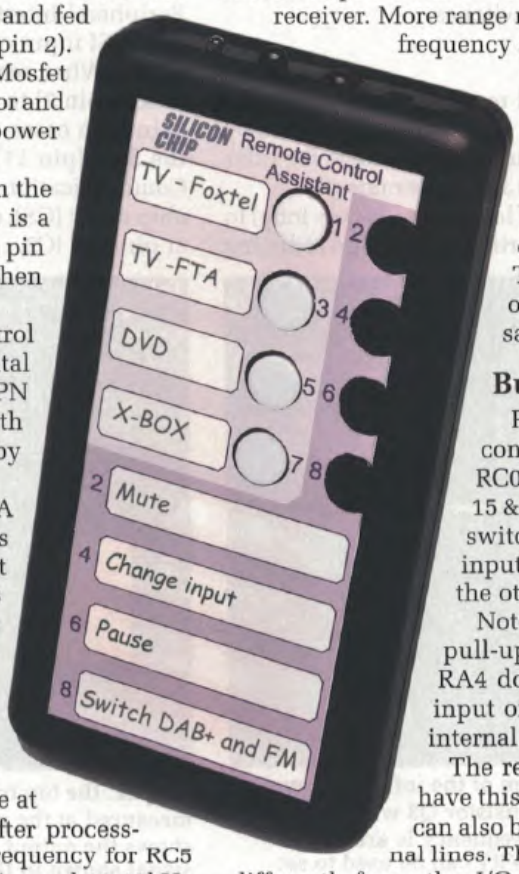
IC1 stores the programmed code sequences in 1Mbit serial RAM chip IC2. Remote control codes from other devices are picked up by infrared receiver IRR1 and fed straight to the RA5 digital input of IC1 (pin 2). IRR1's 5V power supply is switched by Mosfet Q1 and filtered using a 47µF series capacitor and 10µF bypass capacitor, to provide clean power to IRR1; it is sensitive to supply noise.

Mosfet Q1's gate is driven directly from the RC4 digital output of IC1 (pin 6). As Q1 is a P-channel Mosfet, IRR1 is powered when pin 6 is low, and switched off to save power when pin 6 is high.

When transmitting infrared remote control code sequences, IC1 drives its RC5 digital output (pin 5) high. This forward-biases NPN transistor Q3's base-emitter junction, with the current limited to a few milliamps by its 1kΩbase resistor.

When switched on, Q3 sinks about 25mA from the cathode of infrared LED1. It does this in pulses, so the average LED current is less than 10mA during pulses and less if averaged over the whole transmission. The RC5 output is a pulse width modulated (PWM) output running at close to a 32% duty cycle.

Trimpot VR1 adjusts the modulation frequency for infrared LED1. The voltage at its wiper is converted to a digital value at the AN8 analog input of IC1 (pin 8). After processing, this value provides a modulation frequency for RC5 between 34.4kHz when fully anticlockwise and 41.66kHz when fully clockwise.



Infrared remote controls tend to use a frequency of either 36kHz, 38kHz or 40kHz. The adjustment is provided to obtain the best results during use. Typically, setting the frequency to 38kHz (mid-position of VR1) will suit all IR receivers, provided the Assistant is reasonably close to the receiver. More range might be available at a different frequency setting selected with VR1.

The LED indicator (LED2) lights up in response to the IR code during the recording of infrared signals and as a sending data indicator when replaying infrared signals. It is driven via the RC3 output (pin 7) via a 1kΩ resistor. The RC3 output also powers up one side of VR1 when set high, saving 0.5mA the rest of the time.

Button sensing

Pushbutton switches S1-S9 are connected in a 3 x 3 matrix with the RC0, RC1 and RC2 outputs (pins 16, 15 & 14) connecting to one side of the switches and the RA1, RA4 and RA0 inputs (pins 18, 3 & 19) connecting to the other side.

Note that RA1 and RA0 have 100kΩ pull-up resistors to the 3.3V supply, but RA4 does not. That's because the RA4 input of IC1 can be configured with an internal pull-up to 5V, via the software.

The reason that RA1 and RA0 do not have this feature is that on this chip, they can also be used as the USB D+ and D- signal lines. These pins thus operate somewhat differently from other I/O pins when USB mode is disabled. Their pull-ups are designed to suit the USB specifications

rather than be used as general-purpose pull-ups.

The reason that the 100kΩ resistors go to the 3.3V rail rather than the 5V rail is that these USB-specific pull-ups are implemented via internal P-channel Mosfets within IC1, and their sources connect to the +3.3V rail. So if we pulled these pins up to +5V then the 3.3V supply voltage would rise, as the intrinsic reverse diodes in these P-channel Mosfets would conduct.

That would cause the 3.3V supply to rise to around 4.7V. That usually would not be a problem, but we use the 3.3V supply to provide memory backup for IC2. And as we shall see later, this voltage is already near the maximum allowed for that purpose.

That leaves us with the question of whether 3.3V is sufficient for the RA0 and RA1 inputs to differentiate between high and low levels. It turns out that the minimum voltage that is guaranteed to be detected as a high level for these pins is $V_{dd} \div 4 + 0.8V$, which for the highest possible V_{dd} of 5.15V, is still less than 2.1V. So the pull-ups to the 3.3V rail work fine.

To detect if any switch is closed, all RC0, RC1 and RC2 outputs are taken low in sequence. The RA1, RA4 and RA0 inputs will typically be high due to the pull-ups. However, one input will be held low if a switch is pressed. The combination of which of the three sets of pins are low tells us which button was pressed.

Note that if more than one switch is pressed at a time, then the first detected closed switch will be the one that's deemed to be closed. When we require two switches to be closed, such as when clearing memory for an individual switch, switch S9 (the Mode switch) is checked for closure independently from the other switches.

Recording

As described earlier, infrared receiver IRR1 is used for recording the infrared code and its power is controlled by Mosfet Q1. Before recording, the supply voltage for IRR1 is increased slowly to 5V over 13 milliseconds.

This is done by applying brief low pulses (2/3ns long) to its gate, with a repetition rate starting at 66µs and reducing until the gate is held fully low. The reason we do this is so that IC1 does not reset due to a momentary drop in its supply voltage, which can happen if IRR1 is instantly switched on, due to its 10µF bypass capacitor and the limited current that can be supplied by the 9V battery.

Once powered, IRR1 is ready to receive IR codes. Most infrared controllers use a modulation frequency of 36-40kHz. This is done in bursts (pulses), with the length of and space between the bursts (pauses) indicating a code.

The series of bursts and pauses are usually in a particular format (or protocol), and there are several different protocols commonly used.

This includes the Manchester-encoded RC5 protocol originated by Philips. There is also the Pulse Width Protocol used by Sony and Pulse Distance Protocol, originating from NEC.

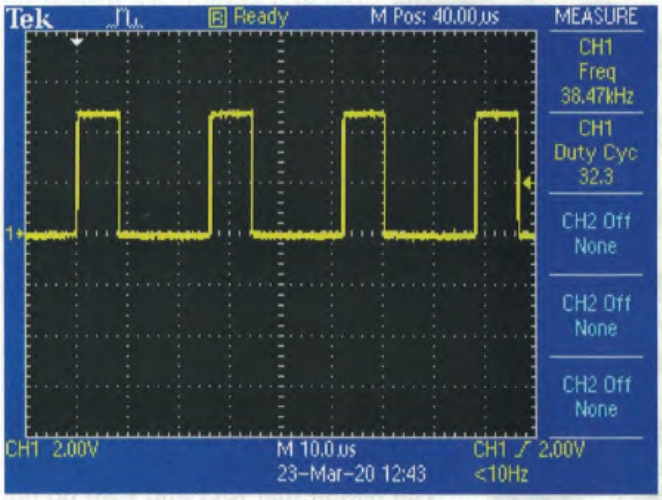
If you are interested in details on all these protocols and others, see the article in SILICON CHIP from June 2019 on the Steering Wheel Audio Button to Infrared Adaptor (siliconchip.com.au/Article/11669).

The output from IRR1 is a demodulated version of the infrared signal, which is high (5V) when there is no signal and low (near 0V) when a 36-40kHz modulated burst is detected. We record the level and duration of each pulse to memory when recording. The recorded sequence is reproduced during playback by modulating LED1 in bursts. It is driven as described above.

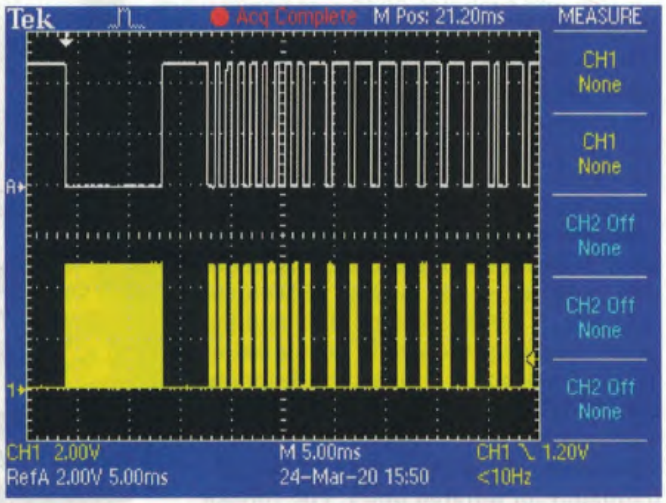
Memory

The memory chip is a 1024kbit (1Mbit) memory organised as 128kbytes. The memory is accessed over a simple Serial Peripheral Interface (SPI) bus. When writing, data is sent to the SI input of IC2 (pin 5) from the SDO (pin 9) output of IC1. When reading, data is received from the SO output of IC2 (pin 2) to the SDI input (pin 13) of IC1.

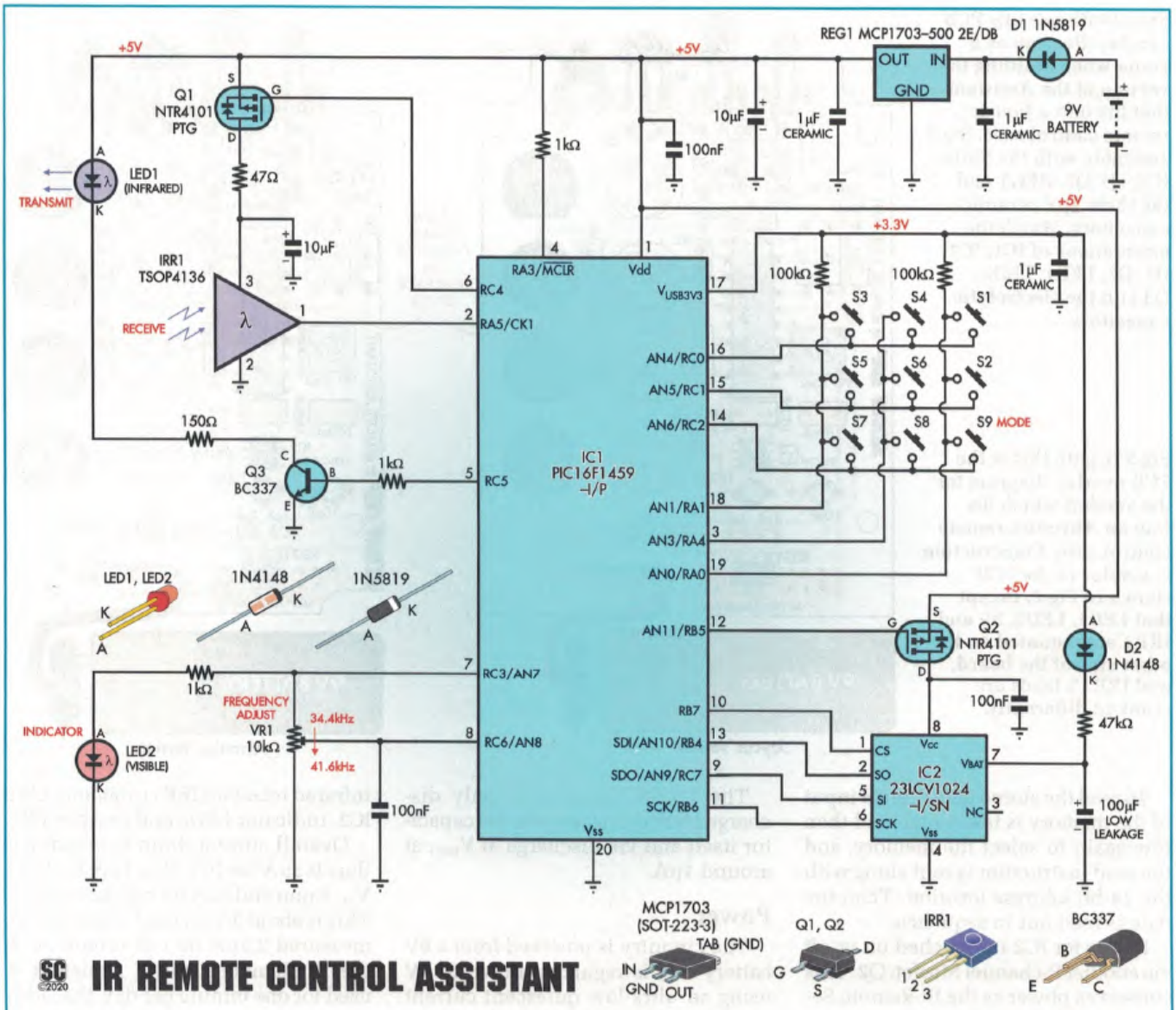
In both cases, the data is clocked using the signal from the SCK (pin 11) of IC1 to the SCK input of IC2, at pin 6. Communication with IC2 is enabled by a low level at the chip select (CS), driven from pin 10 of IC1 (RB7) and sensed at pin 1 of IC2.



Scope1: this shows the modulation of the infrared signal from pin 5 of IC1. This drives transistor Q3 which controls infrared LED1. The modulation frequency is around 38.5kHz, as VR1 is set mid-way. VR1 can be used to set the frequency from 34.4kHz to 41.66kHz. The duty cycle is fixed at about 32%.



Scope2: the top trace is a capture of an infrared signal, measured at the pin 1 output of IRR1. The lower trace shows the output at pin 5 of IC1 after that infrared coded signal shown in the top trace was stored in memory and replayed, which is shown inverted and also modulated at 34.4kHz.



SC IR REMOTE CONTROL ASSISTANT

Fig.1: the circuit of the Assistant is not too complicated. It's based around microcontroller IC1 which records infrared pulses sensed by receiver IRR1 into RAM chip IC2. It can later read these back and reproduce them by flashing infrared LED1 via transistor Q3, when triggered by a press of button S1-S8.

When writing to memory (after power is applied via Q2), the memory is selected by bringing the chip select input low. Then a write instruction is sent, followed by the desired memory address from which to start. This is a 24-bit address sent as three 8-bit bytes. The seven most significant address bits are always zero, since only 17 bits are required to address the 128k bytes.

Following this, data can be written. The memory powers up in sequential mode where the address automatically increments after each byte is written.

The signal from IRR1 consists of a series of high and low levels. These levels are monitored at a fast rate, but we don't store each sampled level directly into memory. That would chew up the memory too quickly. For example, sampling at a rate of 1.5MHz (ie, each 2/3µs) and storing that level in successive bits, the entire 1Mbit of memory would be full after 2/3 of a second!

So instead, we sample the level each 666.66ns, but we don't store this directly in memory. Instead, we continue to monitor the level and record how long it remains at the same level before changing. The level and duration of each pulse are stored every time the level changes.

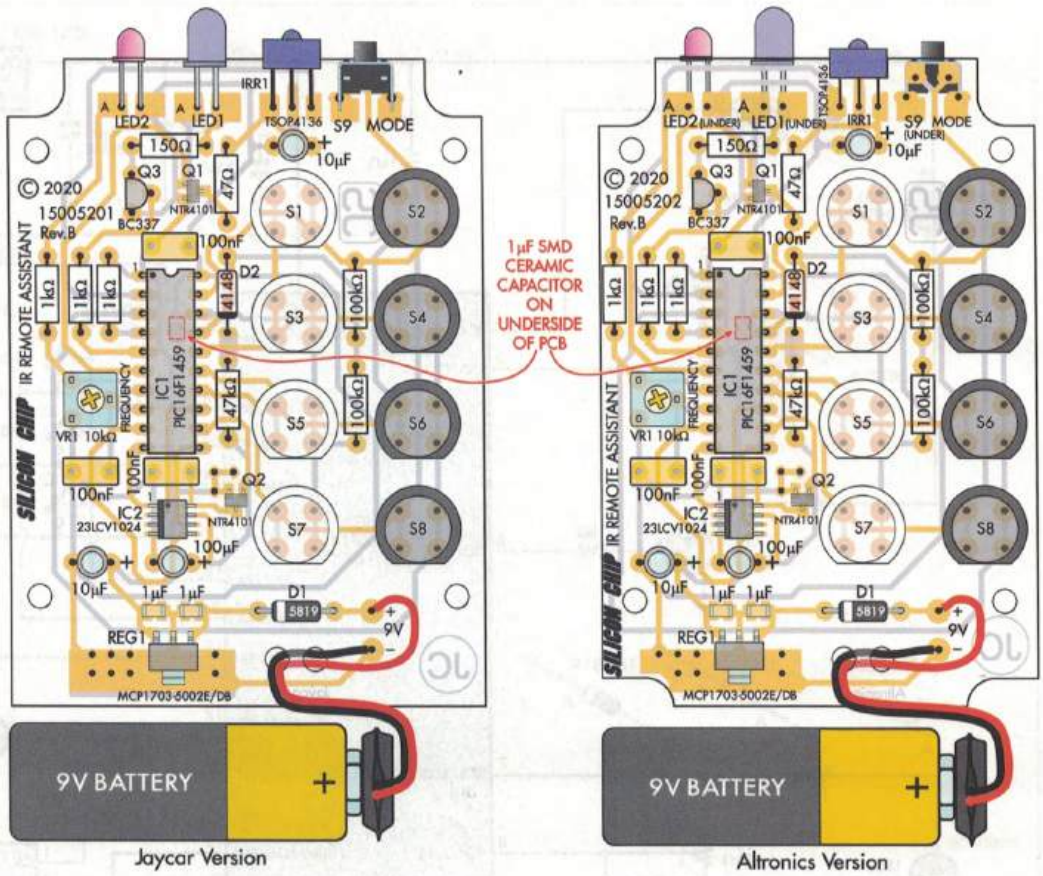
To store this, we use two consecutive 8-bit address locations (16 bits total). The most significant bit (bit 15) stores the level while the remaining 15 bits are used to store the length of the pulse, in 666.66ns intervals.

The maximum value we can store in 15 bits is 32,768, so the maximum period stored in each 16-bit memory location is 32,768 x 666.66ns, or 21.845ms. If the data level does not change within the maximum period, we continue storing the duration of that same level into the next 16-bit wide memory slot. This is a form of 'run-length encoding' data compression.

For our project, we further divide up the memory into eight separate 16kbyte blocks. So the first 16kbyte block is reserved for the sequence stored using switch 1, the second 16kbyte block is for switch 2 and so on, up to switch 8 for the last 16kbyte block.

Fig.2 (left): use this PCB overlay diagram as a guide when building the version of the Assistant that fits into a Jaycar remote control case. Start assembly with the SMDs: IC2, Q1-Q2, REG1 and the three 1µF ceramic capacitors. Watch the orientations of IC1, IC2, D1, D2, LED1, LED2, Q3 and the electrolytic capacitors.

Fig.3 (right): this is the PCB overlay diagram for the version which fits into an Altronics remote control case. Construction is similar to the PCB shown in Fig.2, except that LED1, LED2, S9 and IRR1 are mounted on the other side of the board, and IRR1's leads are cranked differently.



To read the stored data, the CS input of the memory is taken high and then low again to select the memory, and the read instruction is sent along with the 24-bit address location. Then the data is read out in sequence.

Power for IC2 is switched on or off via another P-channel Mosfet, Q2. This conserves power as the IR Remote Sequencer will be sitting dormant most of the time, so it makes sense to power off the memory. It draws around 3mA when active, but only 4µA in standby.

Data stored in the memory is maintained when power is removed from IC2 by supplying a voltage to the battery backup (V_{BAT}) at pin 7. This derives power from the 3.3V supply from the internal 3.3V regulator in IC1 that's intended to power its USB peripheral. This is available at the V_{USB3V3} pin, pin 17. The voltage range for V_{BAT} is 1.4-3.6V, so this 3.3V supply (3.0-3.6V tolerance range) is ideal.

Power for V_{BAT} is applied via D2 and a series 47kΩ resistor. A 100µF low-leakage capacitor holds power to V_{BAT} for a substantial period (more than 100s) during the period while the battery is changed. D2 diode isolates V_{BAT} from the 3.3V supply that will drop to zero when the battery is disconnected.

The 100µF capacitor is only discharged through leakage in the capacitor itself and via discharge at V_{BAT}, at around 1µA.

Power

The circuitry is powered from a 9V battery that is regulated down to 5V using an ultra-low quiescent current regulator that typically only draws 2µA at low output currents. Reverse polarity protection is via schottky diode D1. There are two 1µF ceramic bypass capacitors, one at the input and one at the output of the regulator for supply decoupling and to ensuring regulator stability.

The 5V supply is also bypassed with a 10µF electrolytic capacitor and a 100nF capacitor near IC1.

Saving power

Since we are powering the IR assistant from a battery, power draw needs to be minimised. This is done by only powering parts when they are needed and placing IC1 in a sleep state unless it is required to record or play infrared code. In sleep mode, IC1 typically draws just 0.3µA. IC1 is woken from sleep when a switch is pressed.

Other parts powered off include the infrared receiver (IRR1), memory chip IC2, indicator LED2 and trimpot VR1.

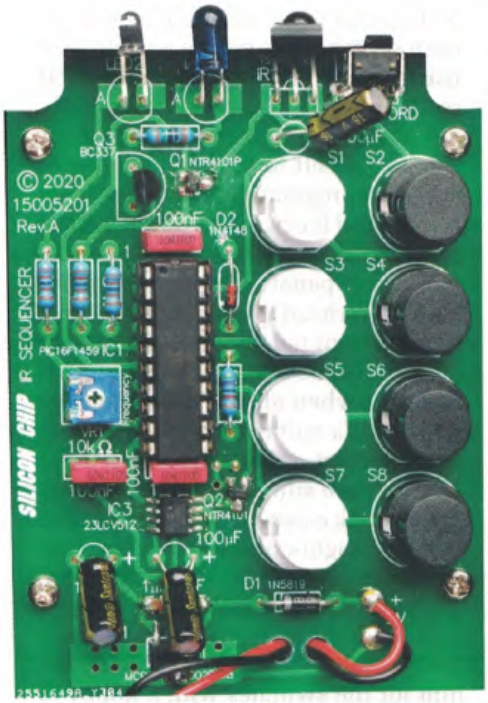
Overall current drain in standby is thus 0.3µA for IC1 plus 1µA for IC2's V_{BAT} input and 2µA for regulator REG1. This is about 3.3µA total, although we measured 2.7µA on our prototype. If the IR Remote Control Assistant is used for one minute per day, that adds about an average of 7µA current draw over the day.

Assuming a conservative 400mAh capacity for a 9V alkaline battery, we can expect the battery to last four years. That's almost the shelf life of the battery itself, which would typically be five years. More frequent usage of the IR Remote Control Assistant will reduce the battery life a little.

Construction

The IR Remote Control Assistant is housed in a remote control case and built on a double-sided PCB.

We've designed two different PCBs to suit different remote control cases. For the Jaycar HB-5610 remote control case, the PCB is coded 15005201 and measures 63.5mm x 86mm. The PCB coded 15005202 and measuring 58.5 x 86mm suits two Altronics cases, either H0342 (Grey) or H0343 (Black).



This same-size photo matches the Jaycar PCB layout opposite (Fig.2) but the Altronics version (Fig.3) is virtually identical, albeit on a slightly narrower PCB. Make sure the battery wiring is threaded through the strain relief holes, as shown here and on the diagrams.

A panel label attaches to the front face of the box in each case, so you know what the unit and its controls do.

Select the correct PCB to suit your case and refer to the relevant PCB overlay diagram: Fig.2 for the Jaycar case or Fig.3 for the Altronics case.

Start assembly by soldering IC2 in place. This is a surface-mounting device, best fitted by placing it in the correct position and soldering one of the corner pins to the PCB pad. Check that the IC is aligned and orientated correctly before soldering the remaining pins. If it is not aligned, remelt the solder on the pin and align the IC again.

Any solder bridges between the leads can be cleared using solder wick to draw up excess solder. Solder wick works best when a little flux paste is applied to the bridge first.

Fit Q1, Q2, REG1 and the three 1µF ceramic capacitors next, using a similar technique. Two of the capacitors are near REG1 while the other is on the opposite side of the PCB, underneath IC1.

Install the resistors next. You can read the resistor colour code to figure out the resistor values, but it's best to use a digital multimeter to measure each value. The diodes can then be installed, and these must be mounted with the orientations as shown. Note that D1 is a 1N5819 type while D2 is a smaller 1N4148.

It's a good idea to mount IC1 using an IC socket. When installing the socket, take care to orientate it correctly. Its notch should be positioned as shown. Then fit trimpot VR1 and transistor Q3.

The capacitors can go in next, with the electrolytic types orientated with the polarities shown (the longer lead is positive). Make sure these capacitors are fitted so that their height above the PCB is no more than 12.5mm; otherwise, the case lid may not fit.

Parts varied by version

LED1, LED2, IRR1 and pushbutton S9 are mounted differently depending on the version you are building. For the version that fits into the Jaycar case, these parts mount on the top side of the PCB.

Bend LED2's leads down by 90°, 6mm back from the base of its lens, making sure the anode lead is to the left. The LED then sits horizontally with the centre of the lens 6mm above the top of the PCB.

Similarly, LED1 mounts horizontally 6mm above the PCB, except its leads should be bent some 4mm back from the lens base, again ensure that the anode is to the left. IRR1 is also mounted with the centre of its lens 6mm above the PCB. Bend its leads in a dog-leg shape, so the front of its lens lines up with the LED lenses.

For the Altronics version, LED1,

Parts list – IR Remote Control Assistant

1 panel label (see text)
1 20-pin DIL IC socket
8 click action pushbutton switches, any colours (S1-S8)
[eg, Jaycar SP0720-4, Altronics S1094-1099]
1 right-angle (RA) tactile pushbutton switch (S9) [Jaycar SP0604]
1 9V battery
1 9V battery clip lead

Semiconductors
1 PIC16F1459-I/P microcontroller programmed with 1500520A.hex, DIP-20 (IC1)
1 23LCV1024-I/SN static RAM, SOIC-8 (IC2) [RS Components 803-2181]
1 MCP1703-5002E/DB 5V ultra-low quiescent current regulator, SOT-23 (REG1) [RS Components 669-4890]
2 NTR4101PT1G P-channel Mosfets, SOT-23 (Q1,Q2) [RS Components 688-9152]
1 BC337 NPN transistor (Q3)
1 TSOP4136 IR receiver (IRR1) [Jaycar ZD1953]
1 5mm IR LED (LED1)
1 3mm red LED (LED2)
1 IN5819 1A schottky diode (D1)
1 1N4148 signal diode (D2)

Capacitors
1 100µF 16V low-leakage (LL) PC electrolytic
2 10µF 16V PC electrolytic
3 1µF 16V X7R SMD ceramic, 3216/1206 size
3 100nF MKT polyester

Resistors (all 1/4W 1% metal film)
2 100kΩ 1 47kΩ 3 1kΩ 1 150Ω 1 47Ω
1 10kΩ mini top-adjust trimpot (5mm pin spacing) (VR1)

Extra parts for Jaycar version
1 70 x 135 x 24mm remote control case [Jaycar HB5610]
1 double-sided PCB coded 15005201, 63.5 x 86mm
4 4G x 6mm self-tapping screws

Extra parts for Altronics version
1 68 x 130 x 25mm remote control case [Altronics H0342 (grey) or H0343 (black)]
1 double-sided PCB coded 15005202, 58.5 x 86mm
4 4G x 9mm self-tapping screws
4 5mm long untapped spacers (or M3 tapped spacers drilled out to 3mm)

LED2, IRR1 and pushbutton switch S9 mount on the underside of the PCB.

For LED2, bend the leads up by 90°, 6mm, from the lens base, making sure that the anode lead is to the left. The LED then mounts horizontally with the centre of the lens 4mm below the bottom of the PCB board. LED1 is also mounted horizontally but 3.5mm below the PCB, with its leads bent some 4mm back from the LED base, again ensuring that the anode is to the left.

IRR1 should also be mounted with the centre of its lens 4mm below the bottom of PCB. Insert its leads from the top and then bend them down by 90° so that the body swings beneath the PCB. A cutout is provided for its leads to pass to the other side of the PCB without sticking out. The back of the lens should be in line with the front edge of the PCB.

More common parts

Switches S1-S8 are mounted orientated as shown, with the flat side to the bottom edge of the PCB. We used four white-topped and four black-topped switches, although any colour or colour combination can be used.

For the Jaycar case, the battery snap is inserted from the battery compartment side first, with the leads passed through to the PCB. For both versions, the leads from the battery snap pass through wire stress relief holes that are on the PCB.

First feed the wires through the outside 3mm hole, then under the PCB and up through the next 3mm hole. Then solder the ends directly to the plus (red wire) and minus (black wire) pads.

Testing

Apply power and check that there is 4.75-5.25V between pins 20 and 1 of IC1's socket. If that is correct, disconnect power and insert IC1. Check that LED2 lights when the Mode switch (S9) is pressed.

Press the Mode switch again so that LED2 goes off. Then press one of S1-S8. The LED should light up. Stop the playback of whatever random data was in the memory chip by pressing any of S1-S8.

Next, clear the memory by pressing the Mode switch (LED2 will light) and holding this switch closed for 10 seconds until the LED flashes to indicate that all memory has been cleared. You can test if the memory has been cleared by pressing any of the S1-S8 switches. If cleared, LED2 will just flash momentarily.

Finishing the case

Drill out the end panel for the LEDs, IR receiver and switch. A drill guide is available and is provided with the front panel label that's included with of the front panel artwork. This can be downloaded from the SILICON CHIP website (www.siliconchip.com.au).

For the Altronics case, it is essential to place the drilling template onto the end panel with the correct orientation before drilling.

The top panel of each case can then be drilled out for the eight switches using the drilling template that's a part of the front panel label artwork. Again, make sure the top panel is orientated correctly before drilling.

Drill a small hole first and gradually enlarge the holes with a reamer. As you enlarge the holes, regularly check that each hole is located correctly and is not too large by placing the panel over the assembled PCB and switches. Countersinking the inside of the holes can help locate the switches better as the panel is brought up to meet the switches.

The front panel artwork includes rectangular blank labelling borders for each switch. This can be written onto using the 'fill and sign' option on a PDF reader before printing. Alternatively, use a fine-point permanent marker on the label itself to indicate what each switch is programmed for. More space is provided for switches S2, S4, S6 and S8 than for S1, S3, S5 and S7.

A front panel label can be made using overhead projector film, with the label printed as a mirror image so the ink will be between the enclosure and film when affixed. Use projector film that is suitable for your printer (either inkjet or laser) and affix using neutral-cure silicone sealant.

For black cases, use a light-coloured silicone. Light-coloured cases can use clear silicone, such as the roof and gutter type. Squeegee out the lumps and air bubbles before the silicone cures. Once cured, cut holes in the film for the switches with a hobby or craft knife.

Other labels and for more detail on making labels, see www.siliconchip.com.au/Help/FrontPanels

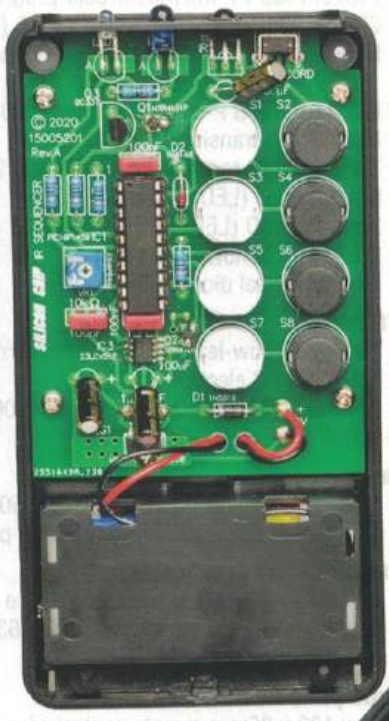
Mounting the PCB

The PCB attaches to the base of the Jaycar case using four self-tapping screws into the integral mounting bushes.

The PCB for the Altronics case is mounted on the lid section using 5mm spacers and 9mm self-tapping screws. If the spacers are M3 tapped, they will need to be drilled out with a 3mm drill to allow the self-tapping screws to enter freely. Finally, attach the lid to the case using the four screws supplied with the case.

Programming it

Orientate the Remote Control As-



The assembled PCB inside the case. Note how some of the components must be tilted to allow the case to close.

Looking at the top of the Jaycar case version – it's simply a matter of "point-n-shoot" – press the button for the previously programmed action required.

sistant with the front end of the case with the LEDs and IR1 facing you and placed near the audiovisual items you are using.

To record the IR sequences required, place the Assistant in record mode by pressing the "Mode" switch using a small probe such as a ballpoint pen. The indicator LED lights, and you then press the button you wish to record a sequence for. The indicator LED flashes in acknowledgement.

The IR Remote Control Assistant is then ready to record a series of infrared codes from one or more infrared remote controls. Ensure that these are aimed at the infrared receiver on the Assistant as you press each button to broadcast the required codes.

Recording does not start until a remote control signal is received. That way, on playback, the code sequence begins straight away. Any pushbutton (S1-S8) can be pressed to end the recording. Further sequences can be stored by pressing the Mode switch again and a using a different pushbutton switch (S1-S8) for each new recording.

At the start of recording, the memory allocated for that pushbutton switch is cleared, ready for a fresh recording. That means that the new recording overwrites any previous recording for that pushbutton switch.

Note that when the IR Remote Control Assistant is first placed in the record mode, record mode will end after ten seconds if one of the S1-S8 switches are not pressed within that time. Similarly, after record mode is initiated and a switch is pressed, it will abort if an infrared code is not received within ten seconds.

If you want to clear the memory for one switch without making a new recording, press and hold the mode switch and then press and hold the switch for the memory to be cleared and hold both for ten seconds. The acknowledge LED will initially flash out the pushbutton number (from 1 to 8) before clearing the memory associated with that switch.

Another method of clearing an individual memory is to press and release the Mode switch and then press the switch associated with the memory you want to clear. The memory is first cleared, and then the IR Remote Control Assistant waits for the receipt of an infrared code. Press any switch to end the recording. The memory will stay cleared since no IR code was received.

Hints and tips

You can record just about any infrared code sequence, but be aware that sequences could get out of synchronisation if you are not careful.

For example, if you program the unit to change from one source to another, the source you select might depend on what source was selected originally.

Also, if one of the receivers misses a code during playback, the following codes could have no effect or the wrong effect.

So you will need to position the transmitter LED in a location where all the receivers will pick it up reliably before playing back a complex sequence, and avoid moving the unit too much during playback or blocking the IR signals. SC

Quick instructions

Modes

There are three modes: Playback, Record and Erase. Playback is the default mode, and the unit is normally in this mode. Record mode is invoked when the Mode switch is pressed and released, after which the indicator LED (LED2) lights. It will automatically return to Playback mode unless a recording is started within 10 seconds.

Bulk erase

Full erasure is performed by pressing and holding the Mode switch alone for 10 seconds.

Individual sequence erase

Press and hold in the Mode switch (S9), then while holding that, press and hold in the pushbutton switch (S1-S8) required for memory erasure. Keep pressing both pushbuttons for 10s until the indicator LED (LED2) flashes out the switch number. Release the switches; the selected sequence has been cleared. LED should now only flash momentarily when that pushbutton is pressed.

Recording a sequence

Place the Infrared Remote Control Assistant near the audiovisual equipment with the front end facing toward you. Press the Mode switch (S9) and release. The indicator LED will light. Press the pushbutton (S1-S8) required for the recording. The indicator will flash off and then on again.

Point the audiovisual remote control(s) toward the audiovisual equipment, making sure it also faces the infrared receiver on the Assistant. Start the sequence by pressing a remote control button for the operation first required within ten seconds. Continue to run through the sequence using the remote control to perform the tasks. The indicator will flash at the infrared encoding rate.

Press any pushbutton (S1-S8) to end the recording.

Sequence playback

Playback mode is the default mode, and in this mode, the indicator LED is off. Point the Infrared Remote Control Assistant toward the audiovisual equipment, then press the required switch (S1-S8). The recorded sequence will be reproduced via the onboard infrared LED.

CIRCUIT NOTEBOOK

Interesting circuit ideas which we have checked but not built and tested. Contributions will be paid for at standard rates. All submissions should include full name, address & phone number.

Novel method of GPS-locking an oscillator

I was inspired to design this circuit by the original GPS-based Frequency Reference project (March-May 2007; siliconchip.com.au/Series/57), which was updated in September 2011. In that design, the microprocessor drove the display, but discrete components were used to discipline the oscillator. I thought a microprocessor could be used to do the disciplining as well.

This circuit was created as a 'proof of concept'. Part of the reason that I am presenting it is that the programmable delay used in the circuit could have other applications. I used a PIC16F628A because that's what the SILICON CHIP circuit used. I chose the other components as they were available at my local Jaycar store.

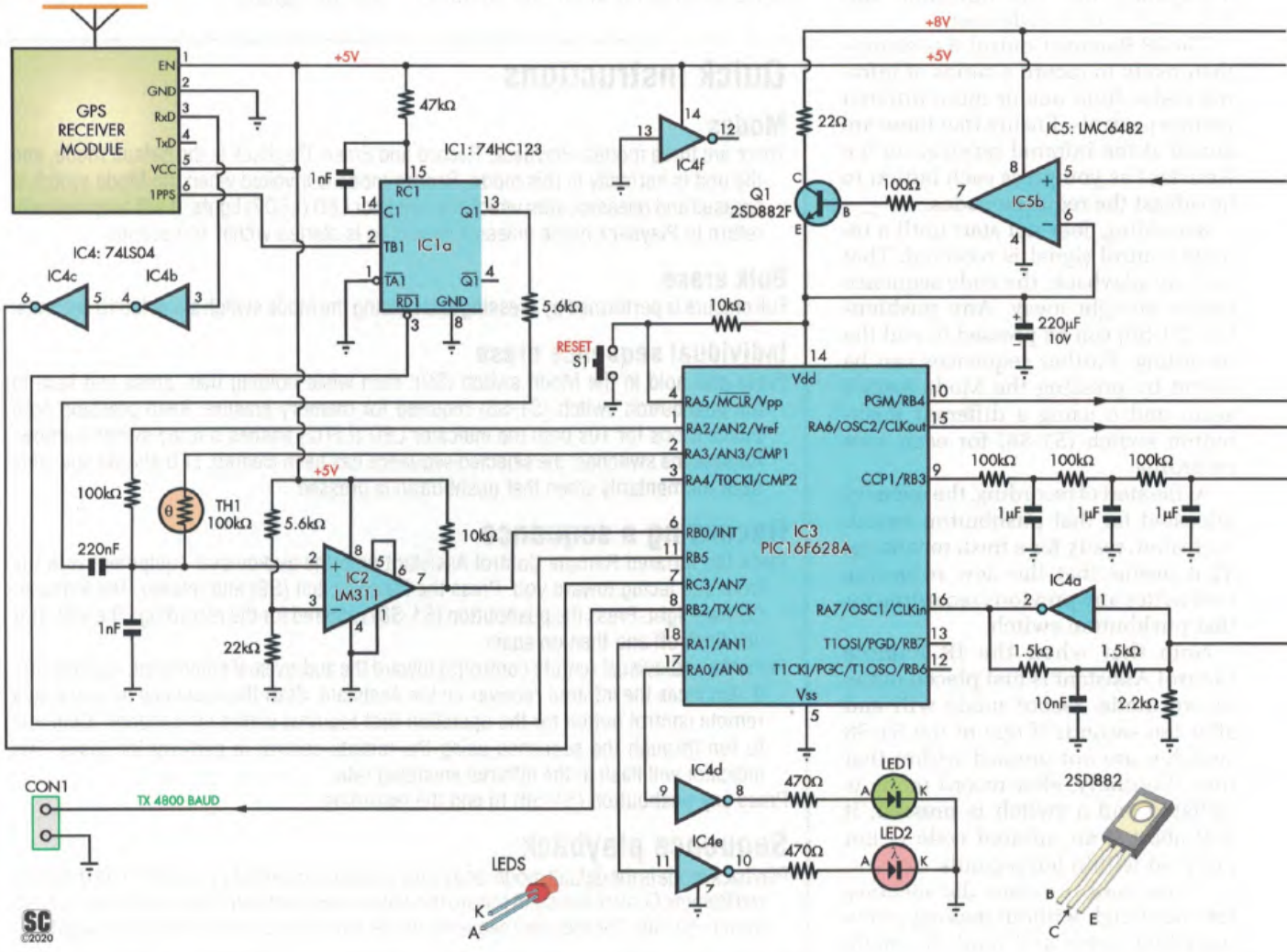
The oscillator itself is a used 10MHz Morion MV89 oven-controlled crystal oscillator (OCXO), which can be purchased on eBay for around $100. It has a 0-5V control input and excellent stability.

The GPS unit is a Holux GR87, which I am using because it has an external antenna input and a 1pps (one pulse per second) output claimed to be accurate "within one microsecond". But otherwise, its specifications are quite poor by today's standards.

With a 'GPS-locked' oscillator, in the long term, no cycles are gained or lost. But in the short term (eg, over 20 minutes), the frequency is allowed to drift relative to the GPS pulses, then that drift is reversed.

By noting the change in control voltage, it is possible to estimate the drift. If it is less than 1 cycle in 20 minutes, an accuracy of better than 1 part in 10^{10} is achieved. This is as good or better than most other home-brew systems.

The OCXO control voltage comes from the microprocessor's RB3 pulse width modulator (PWM) output at



pin 9. The PWM is dithered and filtered, giving adjustment steps of less than 1µV.

The 1pps signal from the GPS module passes through a software-controlled delay circuit based around IC2, which allows changes in the pulse timing to be detected in 16ns steps. This allows the OCXO to drift up to 10 cycles between corrections.

The effect of ambient temperature changes is also partially compensated in software. The software uses statistical methods to calculate the control voltage correction.

Corrections are applied at fixed intervals. The interval was experimentally chosen to balance short-term GPS jitter and long-term oscillator drift. The interval can range from 80 seconds to one day, but I got the best results from 20 minutes to three hours.

The OCXO clocks the microprocessor. The 'heart' of the software system is a timer (TMR2) that resets every 250 instruction cycles, which is every 100µs if the oscillator is accurate. A software counter counts 10,000 reset interrupts to measure a second.

The system counts cycles between the arrival of each GPS pulse and determines if a pulse arrives 'early' (oscillator running slow) or 'late' (oscillator fast).

This is adequate for coarse tuning, but not accurate enough when the oscillator is almost correct. The instruction time is four clock cycles, so it is insensitive to anything less.

Fine-tuning is achieved by the programmable delay circuit. The 1pps pulse first triggers one half of a 74HC123 monostable (IC1a), producing fixed-length pulse for the next part of the circuit. IC1a has a control line ($\overline{RD1}$) which allows the processor to block pulses. This is used if the GPS is not receiving valid data.

The Q1 output of IC1a (pin 13) charges an RC network consisting of a 1nF capacitor and a 5.6kΩ resistor. The 220nF capacitor in series with the 1nF capacitor has little effect on the time constant.

LM311 comparator IC2 detects when the 1nF capacitor is charged to 4V, which in normal operation is a few microseconds after the 74HC123 is triggered.

The programmable part of the circuit is the charge on the 1nF capacitor before the pulse arrives. If it is near 4V before the pulse arrives, the LM311 fires quickly. For lower voltages, it takes longer.

The 1nF capacitor is charged by the processor via a nominal 100kΩ thermistor and discharged through a fixed 100kΩ resistor. This also charges the 220nF capacitor; the charging time constant for both capacitors is in the tens of milliseconds.

The processor charges the capacitors to 4V, then starts discharging them through the fixed 100kΩ resistor before the expected arrival time of the pulse. The period between the start of discharge and detection of the pulse has a nearly linear relationship to the pulse delay. A ~100µs change in starting the discharge changes the delay by 16ns.

For best linearity, the pulse from the 74HC123 should be 4V rather than 5V, but in practice, it makes no noticeable difference.

Because the oscillator frequency is fixed during a measurement period, the arrival of 1pps pulses is tracked by varying the start of discharge and thereby varying the delay. If a pulse arrives late, the delay is increased 16ns; if early, it is decreased by 16ns.

It is assumed that the pulse arrives within 16ns of the interrupt. In the short term, this may not be correct, but in the long term measuring thousands of pulses, the errors cancel out.

The aim is to start the capacitor discharge around 13ms before the 1pps pulse is detected. At the end of a measurement period, the processor calculates the deviation from this target and applies a correction to the control voltage. The aim is to meet the target at the end of the next measurement period.

As the delay circuit is charged via a thermistor, the time to charge varies with ambient temperature and by measuring this, we can implement some compensation to the control voltage for changes in temperature. The advantage of this is that it doesn't matter what causes variations with ambient temperature.

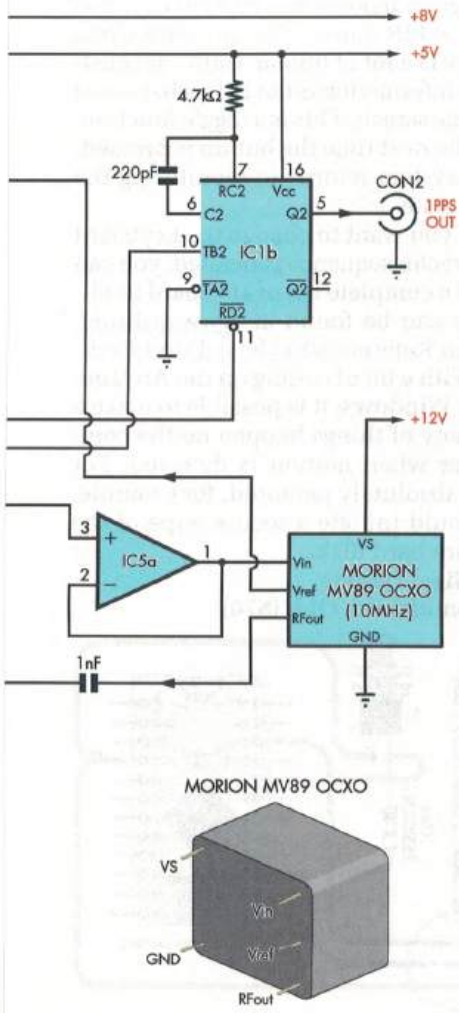
The PWM register is loaded with a new value every TMR2 interrupt, the value derived from a 24-bit number. The least significant 14 bits are added to an accumulator, and if it overflows into the 15th bit, the PWM register is loaded with a value one more than the most significant 10 bits.

Over a second, the PWM output produces a bitstream equivalent to 10 million bits, and the filter output voltage settles on the average. This allows adjusting the frequency of the MV89 (with a specified pulling range of $> \pm 2.5 \times 10^{-7}$) in steps of less than one part in 10^{13}.

The circuit requires +12V, +8V and +5V supply rails. In my prototype, power comes from a surplus 16V laptop supply which is reduced to 12V by an MC78T12 linear regulator. The MV89 requires more than 1A during warm-up, so a 7812 is inadequate. The other two supply rails are derived by 7808 and 7805 regulators.

But note that the +5V rail does not supply PIC IC3. Because the PWM signal provides the control voltage, the processor's supply voltage must be constant.

The MV89 OCXO provides a 5V reference, and this is used to control the supply voltage to the PIC via op amp IC5b (half an LMC6482) and transistor Q1 (2SD882F).



These components buffer the reference output and provide a 5V supply rail to pin 14 of IC3 that accurately tracks the V_{REF} output of the OCXO. All other outputs of the processor are buffered, so it is lightly loaded, assisting in the stability of the supply voltage.

The software is written in PIC assembler and is quite complicated.

The code relies on the relationship between the control voltage and OCXO frequency, and the sensitivity of the delay circuit. These could be determined and written into the program as constants. Since it takes a long time for the OCXO to settle down (an hour or so), the processor uses the time to exercise the circuit and determine the values experimentally. Therefore, no setup is required.

The PIC serial port is used to monitor the GPS messages to determine if it is receiving valid data. The Holux unit continues to produce 1pps signals when it loses the satellites; this crashes the system if they are not ignored. There is the provision to deliver diagnostic information via the TX port at the same baud rate as the GPS input. This is useful for debugging, and for monitoring once the system is working.

LED1 flashes on every received 1pps pulse (as long as it gets through the 74HC123 gate). If an error is detected during the calibration which occurs in the first hour, the LEDs flash a 4-bit binary code to indicate why it aborted. An error condition can also be triggered later if the gap between 1pps pulses and the oscillator gets to the limits of the delay.

Also, for 60 seconds after the 1pps pulses begin, the LEDs indicate the errors in the OCXO output. Within 1Hz, they flash concurrently; if the error is more than 1Hz in either direction, one flashes before or after the other.

It is serendipity that the GPS 1pps triggers the 74HC123 as the GPS has 3.3V outputs and that is close to the minimum input specified for the 74HC123. A 74HCT123 may be a better choice. There could also be better choices of op amp; this may be the component introducing sensitivity to ambient temperature.

The ASM and HEX files for this project can be downloaded from the Silicon Chip website.

Alan Cashin,
Islington, NSW. ($120)

USB privacy dongle emulates keyboard

For the many years that I have worked as a consultant, there have been times when I have had confidential documents open on my computer screens. If someone walks into my office while I'm reviewing these documents, I must quickly minimise them.

Suddenly hiding documents with a flurry of keystrokes is not polite. So I decided to build a small device that would perform a similar task automatically.

Linux and modern versions of Windows can have multiple desktops. On Windows, this is available through the "Task View" function. To swap between desktops requires three keys pressed simultaneously: the Windows key, the Ctrl key and the left or right arrow, to move to the screen to the left or right of the current one.

This circuit uses an Arduino Pro Micro board and a passive infrared (PIR) motion detector to automatically trigger this function when movement is detected. It can be aimed at a doorway, so that if someone walks through that doorway, the desktop view automatically changes.

The Arduino Pro Micro has an ATmega32u4 microcontroller with hardware USB support. This allows it to easily emulate a human interface device (HID) such as a mouse, joystick or a keyboard. There are three popular boards with that microcontroller: the Arduino Leonardo, Teensy 2.0 and Pro Micro. The Pro Micro costs about $10-15. A compatible PIR motion detector module costs about $5.

The only other components required are one resistor and a pushbutton switch.

The PIR sensor module has three connections: +5V, 0V and sensor. The sensor wire is connected to pin 7 of the Arduino board and the PIR jumper is set for a single trigger. The button is wired up to pull Arduino pin 2 high when pressed, while the 10kΩ resistor keeps that pin low the rest of the time.

There is an onboard LED designated RxLED, which is used to indicate PIR detection.

Use the Arduino Integrated Development Environment (IDE) to compile and upload the sketch for this project (privacy_keyboard_dongle.ino) which can be downloaded from the Silicon Chip website. You will need to select the correct board (Arduino Pro Micro) and COM port from the menus first.

The code loads the keyboard library, defines the I/O pins and sets the initial states and variables. The pushbutton debounce time is set to 200ms.

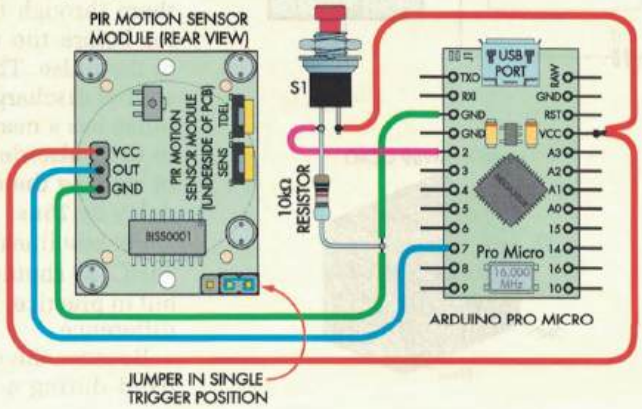
At power-up, it waits for 15 seconds for the PIR to settle. It then monitors the state of the PIR output and the pushbutton. If motion is detected, the internal RxLED is lit and the Windows key + Ctrl key + left arrow sequence is sent to the computer. Windows will change to the previous desktop screen. You can manually change back to the other screen (Windows + Ctrl + right) when you are ready.

If the pushbutton is pressed, the onboard LED is switched off and the program ignores any motion detected by the PIR sensor. This is useful when there is a lot of human traffic or sensitive information is not being displayed on the screen. This is a toggle function, so the next time the button is pressed, the system returns to monitoring the PIR state.

If you want to change the keyboard character sequence generated, you can find a complete list of keyboard modifiers can be found at www.arduino.cc/en/Reference/KeyboardModifiers

With a bit of coding on the Arduino and Windows, it is possible to make a variety of things happen on the computer when motion is detected. For the absolutely paranoid, for example, it could initiate a secure wipe of the entire hard disk.

Nigel Quayle,
Smithfield, Qld. ($70)



Running Micropython on an ESP32/ESP8266

ESP32 boards can be programmed in a C++-derived language using the Arduino IDE. But some may find programming in Python easier. This is possible by loading the MicroPython firmware onto an ESP32 chip. You can do this using a Raspberry Pi.

First, download and copy the latest "esp32.bin" file to the Pi. You can get this from http://micropython.org/download#esp32

Next, install "esptool" using pip at a command prompt:

```
sudo pip install esptool
```

Connect the ESP32 board to the Raspberry Pi with a USB lead. Use the "dmesg" command to find the USB port that has been allocated (probably /dev/tty/USB0):

```
dmesg | grep ttyUSB
```

To erase any software currently on the ESP32, use this command:

```
sudo python esptool.py --chip
  esp32 --port /dev/ttyUSB0
  erase_flash
```

If you have an ESP8266 chip, use this command instead:

```
sudo python esptool.py --port
  /dev/ttyUSB0 erase_flash
```

To load the MicroPython firmware onto an ESP32 (the esp32.bin file must be in the current directory):

```
sudo python esptool.py --chip
  esp32 --port /dev/ttyUSB0
  --baud 460800 write_flash -z
  0x1000 esp32.bin
```

For an ESP8266, use this command:

```
sudo python esptool.py
  --port /dev/ttyUSB0
  --baud 460800 write_flash
  –fl ash_size=detect -fm dio 0
  esp8266.bin
```

To set up the WiFi on the ESP32, connect it to a Windows PC via USB. You may need to download a cp210x driver for it to be identified (it should be included with Windows 10, otherwise you can find it at siliconchip.com.au/link/aalb).

Go to Device Manager, and under "Ports" you will see a COM port starting with "Silicon Labs". Note the COM port number.

Run Putty (a free download if you don't already have a copy), and create a new serial port session, with the COM port set to match the Silicon Labs device. Set the baud rate to 115,200.

In the Putty connection dialog, on the left-hand side, click "Serial", and change Flow Control to None. Then connect to this session. You should see a MicroPython prompt, which looks like three greater-than symbols: ">>>".

To set up a WebREPL connection, to allow for WiFi access, type:

```
import webrepl_setup
```

Enter "E" to enable at startup, and record the password that you enter. Reboot when prompted. Now start the AP software:

```
import network
ap = network.WLAN(network.AP_IF)
# sets the ssid to ESP-AP
ap.config(essid='ESP-AP')
# Starts the Access Point
ap.active(True)
# ('192.168.4.1','255.255.255.0',
  '192.168.4.1','8.8.8.8')
ap.ifconfig()
ap.active() # True
```

Other settings (used later) include:

```
# Start the Station Interface
sta.active(True)
# Connect to WiFi AP
sta.connect('<your ESSID>',
  '<your password>')
# Checks Connection
sta.isconnected()
sta.ifconfig()
```

To disable the Access Point:

```
ap.active(False)
```

Now, with the board still plugged into your PC, you need to connect to it over the WiFi network. To do this, download the MicroPython WebREPL client for Chrome from http://micropython.org/webrepl "webrepl_master.zip" is the file you need. Unzip this and extract "webrepl.html" and "term.js".

Ensure you have the Chrome browser installed and set as your default browser. Double click the "webrepl.html" file, which should load in Chrome. Connect your PC's WiFi adaptor to the network with an SSID of ESP-AP (no password is required at this stage).

Then, in the Chrome window, click on "Connect" (IP = 192.168.4.1). Set the password you used previously. Once connected, press CTRL-C to interrupt any running script. You will have the python prompt: ">>>".

Now you can send the "main.py" file to the ESP32. This is the program that runs when the device is first powered up. To upload this file, click on "Choose file", and navigate to the "main.py" file you want to upload (your program). Select "Send To Device". This takes about five seconds. Then click "Disconnect".

You can now unplug the ESP32 board from your PC and power it with a plugpack or other DC supply. The main.py program will run as soon as it's powered up and do whatever you have programmed it to do.

Note that, once you've uploaded the main.py program, the WiFi behaviour changes. At boot time, an Access Point is started on the ESP with an SSID of "ESP_xxxxxx", where the "xxxxxx" is the last six characters of the device's MAC address. If you connect your PC to this WiFi network, you can connect to it via the Chrome plugin at 192.168.4.1:8266 with Chrome (no WiFi password needed).

But you cannot connect when the ESP32 is in deep sleep mode.

To run a Python file other than main.py, you can import it with:

```
import sidtest.py
```

But you can only import (and run) a file once per session this way.

To remove files from the device, use the following commands:

```
import os
os.listdir() # lists all files.
# removes one file
os.remove("main4.py")
```

To change the webrepl password:

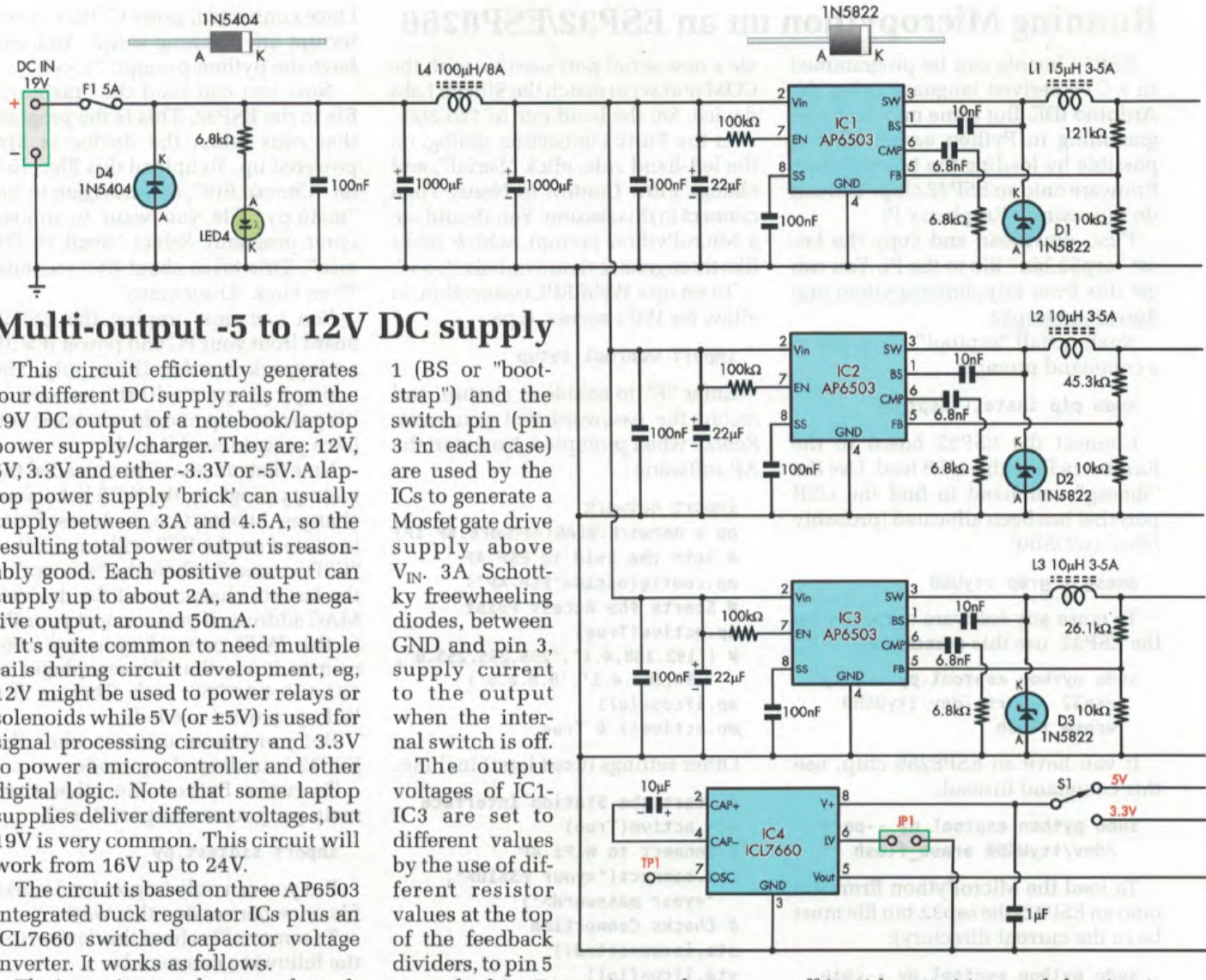
```
import webrepl_setup
```

Follow prompts to enable at startup, and change the password. To check the WiFi connection:

```
sta.status() # or ap.status()
sta.active()
sta.isconnected()
sta.disconnect()
sta.connect('SSID','password')
sta.ifconfig()
```

Warning – sta.status(), and sta.isconnected() both report all OK even if you have supplied the wrong WiFi network password.

Sid Lonsdale,
Whitfield, Qld. ($80)



Multi-output -5 to 12V DC supply

This circuit efficiently generates four different DC supply rails from the 19V DC output of a notebook/laptop power supply/charger. They are: 12V, 5V, 3.3V and either -3.3V or -5V. A laptop power supply 'brick' can usually supply between 3A and 4.5A, so the resulting total power output is reasonably good. Each positive output can supply up to about 2A, and the negative output, around 50mA.

It's quite common to need multiple rails during circuit development, eg, 12V might be used to power relays or solenoids while 5V (or ±5V) is used for signal processing circuitry and 3.3V to power a microcontroller and other digital logic. Note that some laptop supplies deliver different voltages, but 19V is very common. This circuit will work from 16V up to 24V.

The circuit is based on three AP6503 integrated buck regulator ICs plus an ICL7660 switched capacitor voltage inverter. It works as follows.

The incoming supply passes through fuse F1, which will blow if the supply polarity is reversed, as diode D4 will then conduct. LED4 lights up when voltage is present at this input. The supply voltage is filtered using a pi filter comprising two 1000µF capacitors and 8A inductor L4. It is then fed to the supply pins (pin 2) of IC1-IC3.

Each IC also has its own pair of supply bypass capacitors, 100nF and 22µF. The 100nF capacitor is more effective at higher frequencies, while the 22µF provides bulk bypassing. Each of these three ICs has its enable pin (pin 7) pulled high via a 100kΩ resistor, so they are always operating when the supply voltage is present. They also all have identical 100nF soft-start timing capacitors between pin 8 and GND.

Each IC also requires a compensation network between pin 6 and GND for stability; in this case, all three are identical. 10nF capacitors between pin 1 (BS or "bootstrap") and the switch pin (pin 3 in each case) are used by the ICs to generate a Mosfet gate drive supply above V_{IN}. 3A Schottky freewheeling diodes, between GND and pin 3, supply current to the output when the internal switch is off.

The output voltages of IC1-IC3 are set to different values by the use of different resistor values at the top of the feedback dividers, to pin 5 on each chip. E96 resistor values are used to give accurate output voltages without the need for trimming. The values of inductors L1-L3 have been chosen to suit those output voltages.

Each output has one LED (LED1-3) which lights when that output is powered. The current limiting resistors have been chosen to give equal brightness. Each output also has four different value filtering capacitors, to give low impedance across a wide range of frequencies.

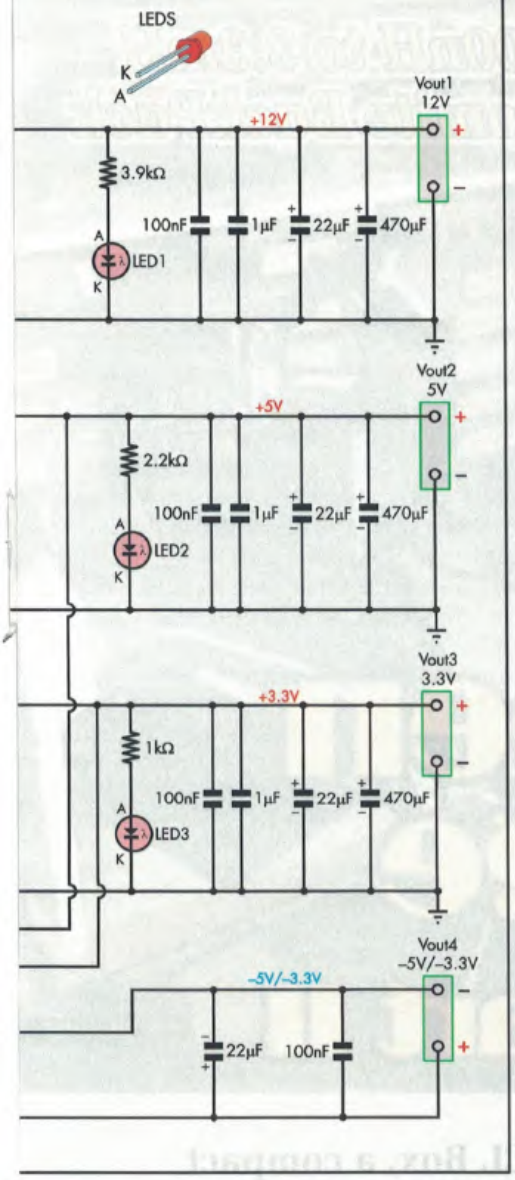
Either +5V or +3.3V is fed to input pin 8 of voltage inverter IC4, depending on the position of switch S1. A charge pump is formed by transistors internal to IC4 and the 10µF capacitor between pins 2 and 4, to generate a -3.3V or -5V rail at pin 5.

JP1 can be inserted to increase the output current available when generating -3.3V, **but it must be left off when S1 is in the 5V position**. It may be left off in either position, and the circuit will still operate. IC4's switching frequency can be monitored at TP1.

Note that it is possible to substitute the Richtek Technology RT8250 instead of the AP6503 from Diodes Inc, however, the compensation network needs to change in this case (see the RT8250 data sheet for details). Also note that you could change the output voltages by varying the upper divider resistors and inductor values; see the AP6503 data sheet for details.

It's a good idea to solder IC1-IC3 to a large copper area for heat dissipation, or failing that, glue a small heatsink on top of each IC. Note that if you are drawing a significant current from multiple outputs simultaneously, it is possible to overload the mains supply, in which case it will most likely shut down.

Petre Petrov,
Sofia, Bulgaria. ($75)



Circuit Ideas Wanted

Got an interesting original circuit that you have cleverly devised? We will pay good money to feature it in Circuit Notebook. We can pay you by electronic funds transfer, cheque or direct to your PayPal account. Or you can use the funds to purchase anything from the SILICON CHIP Online Store, including PCBs and components, back issues, subscriptions or whatever. Email your circuit and descriptive text to editor@siliconchip.com.au

Digital soldering iron timer with relay

My previous Circuit Notebook entry (November 2019, siliconchip.com.au/Article/12095) described a soldering iron timer which would give the user an alert if the iron was left on for too long, but would not switch it off. That is rectified in this circuit, which is virtually identical except that the common cathode resistor for the LED bargraph connects to the base of NPN transistor Q1, rather than ground.

This still lets the LEDs light, as their forward current can flow through Q1's base-emitter junction to ground, but it also means that Q1 is switched on whenever any of the LEDs are lit. Q1 drives the coil of 12V DC relay RLY1, which is used to switch the Active connection to a mains socket for the soldering iron.

So when you switch on the timer unit, the top bargraph LED segment lights, the contacts of relay RLY1 close and the soldering iron is powered up. Over time, the lit LED makes its way down the bargraph unless you use pushbutton S2 to reset it. Eventually, after the selected period has elapsed (which can be set using S2, as explained in the November issue), all the LEDs go out and the iron switches off.

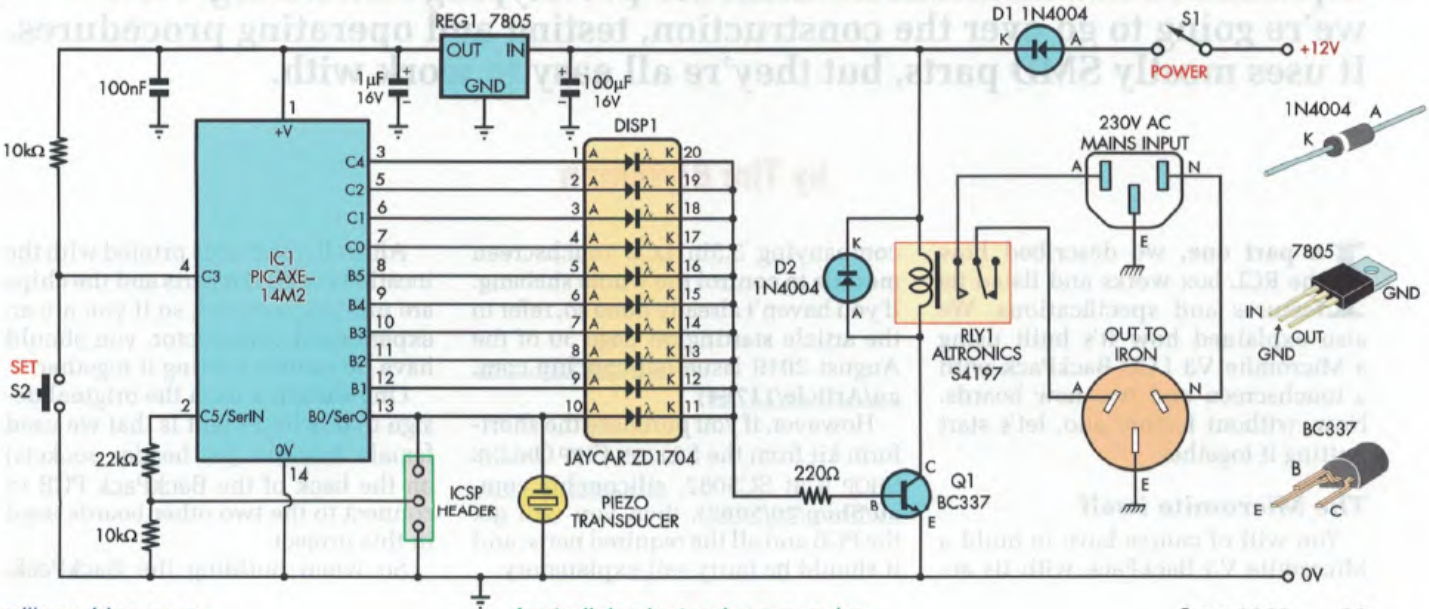
You get a little bit of warning before this happens, since the piezo transducer produces a sound when the bottom-most LED segment is lit. So you have a chance to press S2 to reset the timer before the iron switches off if you are still using it.

As this design involves mains wiring, use properly rated wire, insulate all exposed metal and build it into a sturdy case (which must be Earthed if it is made of metal). You should also add an insulating barrier between the low-voltage and high-voltage sections. Don't build it if you don't know how to wire mains equipment; our more detailed mains-based project articles are a better option for beginners.

The software for this version of the timer is slightly different than the last one; you can download the new file, named "timer iron2_14m2.bas", from the SILICON CHIP website.

Ian Robertson,
Engadine, NSW. ($50)

WARNING! – This circuit involves mains wiring and contact with live components is potentially lethal.



• 1Ω to 10MΩ, • 10pF to 10µF, • 100nH to 3.3mH
• Programmable • Based on Micromite BackPack

Touchscreen Wide-range RCL Box Part II

Last month, we described our new touchscreen RCL Box, a compact device that lets you quickly and easily select various resistance, capacitance and inductance values for prototyping and testing. Now we're going to go over the construction, testing and operating procedures. It uses mostly SMD parts, but they're all easy to work with.

by Tim Blythman

In part one, we described how the RCL box works and listed its features and specifications. We also explained how it's built using a Micromite V3 LCD BackPack with a touchscreen and two new boards. Now, without further ado, let's start putting it together.

The Micromite itself

You will of course have to build a Micromite V3 BackPack with its accompanying 3.5in LCD touchscreen module to control the whole shebang. If you haven't already done so, refer to the article starting on page 30 of the August 2019 issue (siliconchip.com.au/Article/11764).

However, if you purchase the short-form kit from the SILICON CHIP ONLINE SHOP (Cat SC5082, siliconchip.com.au/Shop/20/5082), then you will get the PCB and all the required parts, and it should be fairly self-explanatory.

After all, the PCB is printed with the locations of all the parts and the chips are pre-programmed, so if you are an experienced constructor, you should have no trouble putting it together.

One variation from the original design that is important is that we used female headers (ie, header sockets) on the back of the BackPack PCB to connect to the two other boards used in this project.

So when building the BackPack,

The RCL box has three sets of terminals (right side) so you can use the resistance, capacitance and inductance functions independently of each other. It's all under the control of the Micromite Backpack (V3) which allows you much more flexibility than traditional R, C or L substition boxes.

it's probably a good idea to leave the external I/O and power/serial headers off initially, and fit them later, after you've built the other board.

There's also not much point in mounting the LCD yet. Fit the headers and test that the Micromite connects to the LCD, but don't install the mounting hardware at this stage.

Note that any 'optional' components fitted to the BackPack may interfere with the RCL Box operation if they share pins; these should be removed if already fitted.

Construction

We suggest that you carefully follow these instructions and build the boards in the order given, or you may find it a bit tricky.

While none of the parts are tiny, you should avail yourself of the usual set of SMT tools, including a fine-pointed, temperature adjustable soldering iron, tweezers, magnifier, solder flux and braid (wick).

Some flux removal solution or even isopropyl alcohol will be handy to clean up any excess flux; in general, more flux is better than not enough!

The consequence of this is that the PCBs are left with a messy residue unless cleaned.

Since both boards have mostly components only on one side, they are well suited to reflow soldering. See our articles on building a Reflow Oven from April and May 2020 (siliconchip.com.au/Series/343).

With the design effectively cramming four PCBs into the UB3 Jiffy box, once finished, space will be tight. So as you progress through the assembly steps, be careful of components standing higher than needed.

In particular, the relays should protrude from the board no more than 7mm; use the parts we have specified (which are around 5mm tall) or check the data sheet of alternative parts before ordering.

The low-profile Panasonic TQ2SA-5V relays we used are not commonly available but they are in stock at two SILICON CHIP advertisers: DigiKey and Mouser. We understand they would qualify for free shipping.

Naturally, positioning of the parts is critical for correct operation; if any of the resistors, capacitors or inductors are mixed up then the software won't be able to produce the correct values.

Resistor PCB

We'll start by building the resistor PCB which is coded 04104201 and measures 115x58mm. Its PCB overlay diagram, Fig.3, has been repeated from last month to help you during the assembly.

First, check that you have the correct PCB; the two main boards look very similar.

For all the components, we suggest the following process.

Apply a small amount of flux to the pads and hold the component in place with tweezers. Add a small amount of solder to the iron and apply the iron to one lead.

For the larger relays, you may be able to hold them in place with a well-placed finger; their larger body will present less risk of being burnt. Once the component is flat, square and centred, solder the other pin(s).

Start with the resistors. Apart from one 10kΩ resistor near the Micromite header, they are all down the centre of the board. We suggest you start at one

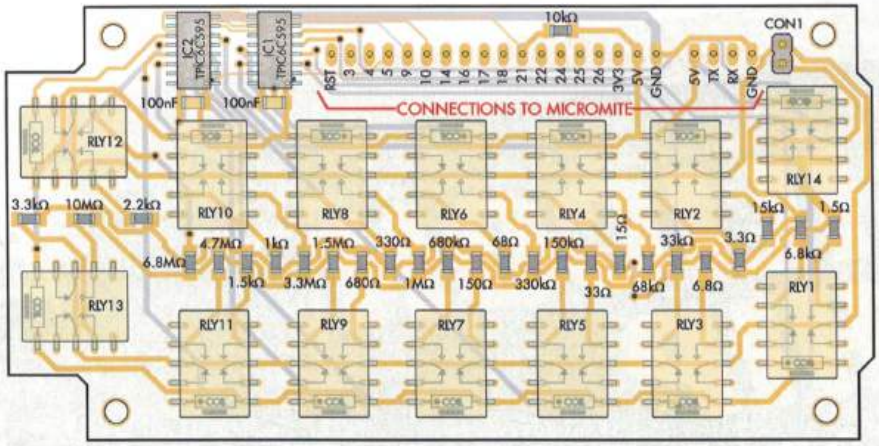
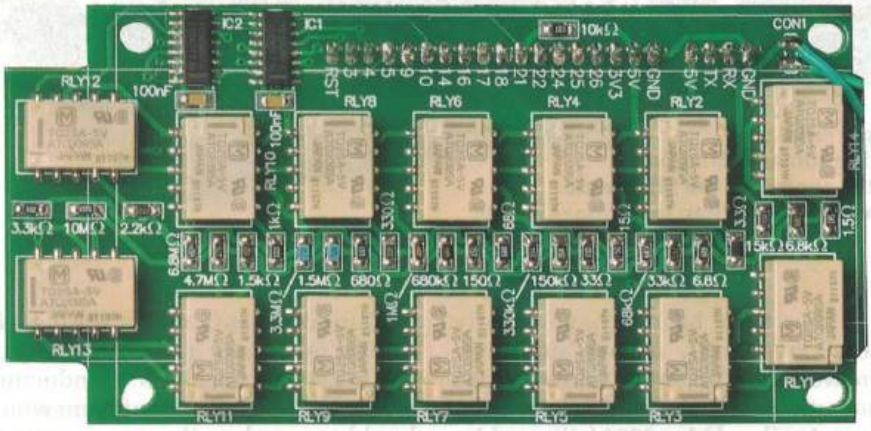


Fig.3: the PCB overlay diagram for the resistor board, reproduced from last month. Be careful to orientate the relays correctly, as shown here, and add the parts in the order stated in the text to make your life easier. If you have a magnifier, you can read the value codes on the individual resistors.



end and work your way along, ensuring that the value printed on the part matches the silkscreen.

We have repeated the relevant section from last month's parts list for the expected SMD component markings (Table 1).

You should be able to confirm their resistances, even after they are soldered, as they are connected to the (absent) relays at one end, ensuring that their measured values are not distorted by being connected to other components.

There are two 100nF capacitors; they are interchangeable and non-polarised. Ensure they are fitted accurately, as there is not much space around them once installed.

The two ICs have the finest pitch footprints on the PCB (although they aren't very close by SMD standards). It is vital to ensure that the pin 1 dot lines up with the silkscreen. If you cannot see it, pin 1 is also closest to the 100nF capacitor.

Proceed with the ICs as for the other parts, but do not be concerned if a solder bridge forms, as long as the part is aligned correctly. Finish soldering the remaining pins and once the part is secure, use solder braid to carefully remove any excess from one side at a time.

Before adding the higher-profile relays, now is a good time to clean up any flux residue according to the instructions on your flux cleaning solution.

There are fourteen relays to be fitted, all with their pin 1 markers facing the outside of the PCB. You can confirm this from the silkscreen and also the fact that the pin 1 pad is square instead of rounded. Check your progress against our photos.

Our relays also have a stripe printed on their tops which should match the stripe printed on the PCB silkscreen.

Leave RLY12 and RLY13 until last; they are oriented differently and have more space around them; this gives you better access to RLY10 and RLY11's pins when fitting those parts.

The spacing is quite tight, but the same techniques apply as for the other components. Using a fine-pointed soldering iron, come in almost perpendicular to the PCB so as not to burn and damage adjacent relays. The pins on the relays are at a generous 0.1in (2.54mm) pitch.

Do not add the Micromite headers yet. If you are keen, you might like to run some jumper wires from a Micromite to test the resistor PCB in isolation, although you will naturally need the software installed to do this (as described below).

Capacitor/inductor PCB

Well recruits, this is what you have been training for. Not only are there 16 relays on this side of the PCB, but many of the components also don't have any markings. Take care not to mix them up. But you should find that the process is much the same as for the resistor PCB.

Start with the capacitors, checking the component value as you go. If you have a capacitance meter, you can use it to double-check that the correct parts have been fitted.

As well as the output capacitors, there are two 100nF parts for bypassing the ICs and a single 10kΩ resistor

Resistor Codes (all 1 of each, SMD 1% 3216/1206 size; SMD markings shown)

10MΩ	106 or 1005	6.8MΩ	685 or 6804	4.7MΩ	475 or 4704
3.3MΩ	335 or 3304	1.5MΩ	155 or 1504	1MΩ	105 or 1004
680kΩ	684 or 6803	330kΩ	334 or 3303	150kΩ	154 or 1503
68kΩ	683 or 6802	33kΩ	333 or 3302	15kΩ	153 or 1502
10kΩ	103 or 1002	6.8kΩ	682 or 6801	3.3kΩ	332 or 3301
2.2kΩ	222 or 2201	1.5kΩ	152 or 1501	1kΩ	102 or 1001
680Ω	681 or 680R	330Ω	331 or 330R	150Ω	151 or 150R
68Ω	680 or 68R0	33Ω	330 or 33R0	15Ω	150 or 15R0
6.8Ω	6R8 or 6R80	3.3Ω	3R3 or 3R30	1.5Ω	1R5 or 1R50

Table 1: reproduced from the parts list in the June issue, this shows the codes you can expect to be printed on the SMD resistors.

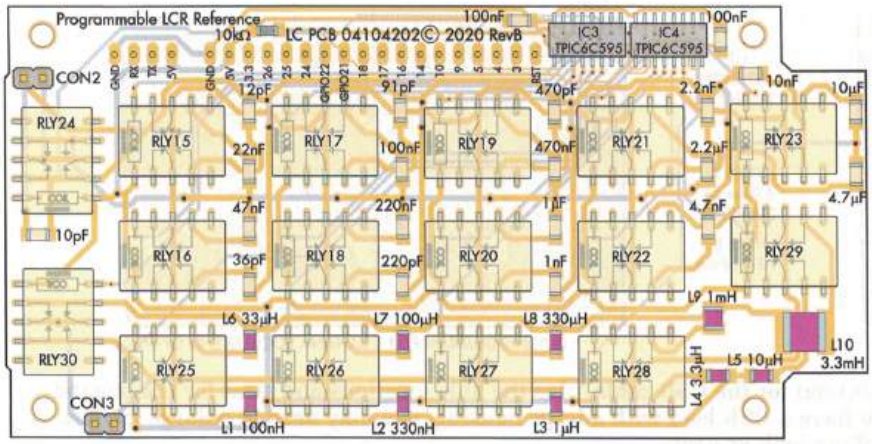
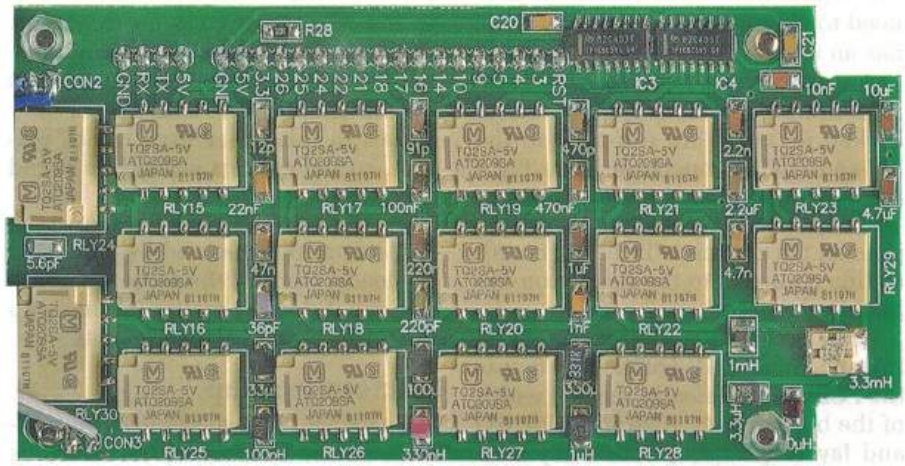


Fig.4: the capacitor/inductor board has more relays and some larger components, so it's a bit packed. But if you follow our instructions, you should not find it too difficult. Again, watch the orientation of the relays. The inductors should have printed values but the capacitors won't.



to fit. As for the resistor PCB, the two ICs have the closest pin spacings. Note that pin 1 on both is closest to the Micromite header.

Following on from this, fit all the inductors except the 3.3mH type. It is larger and can be fitted last, even after the relays.

With all the low-profile parts fitted, clean up excess flux before moving onto the relays.

If you have any doubts, now is the time to test the part values, as fitting the relays will make it more difficult to do so.

Proceed with the relays as you did for the resistor board. Patience will help!

Take note of the orientation markings; most of the relays face the same direction, but the two mounted at right angles face towards each other. We suggest fitting RLY24 and RLY30 before the remainder, as they have the smallest clearances to adjacent components.

Finally, fit the 3.3mH inductor. It has the largest pads and so may need more heat. It's best to apply a thin smear of flux paste to its pads before placing it. When finished, clean up any remaining flux residue.

Mechanical assembly

While the boards we supply are both covered with a solder mask layer, providing a degree of insulation if the boards are laid flat against each other, you should not rely on this.

Here's a trick we even seen some manufacturers perform; stacking multiple capacitors to achieve a higher capacitance value. In this case, we have combined a pair of 4.7µF parts to replace a single 10uF part. It's not hard to do as long as you don't apply to much heat.

The solder mask appears durable, but is thin and will not resist much vibration or chafing, and it can even come from the factory with a few holes (especially around vias).

So cover the back of one of the boards with Kapton (or similar polyimide type) tape, except for around the Micromite headers and the four mounting holes.

While CON1, CON2 and CON3 appear to pass through the board, the tape can sit against the back of these; this will help to insulate their pins from the other board. We've used through-hole pads here to provide more mechanical strength as surface-mounting pads are more easily torn off the PCB.

Assuming you have built the Micromite V3 BackPack with LCD as described above, fit the 18-way and 4-way female headers on its back side.

Note that the Micromite BackPack usually has male headers in these positions.

Rather than using multiple threaded spacers with machine screws front and back, we used a different technique for the board stack.

Mount the LCD to the front panel/lid piece using four 32mm-long M3 machine screws, with 1mm Nylon washers to separate the acrylic panel from the LCD and the 12mm threaded spacers generally used with the BackPack, to secure the machine screws to the LCD panel.

Add the Micromite BackPack to the stack, then place 9mm tapped or untapped spacers onto the exposed threads. Add the resistor PCB with its relays facing the BackPack, then the capacitor/inductor PCB with its relays facing away and then secure the whole lot with four hex nuts.

Although we haven't made the electrical connections yet, you should now have a good idea of the overall size of the PCB stack.

Before soldering anything, you might like to test fit the stack into the Jiffy box. This will let you know how much room there is left. If you've used the 5mm-tall relays we've specified, you should have around 2mm clearance left.

We now need to use a pin header to connect the two PCBs to each other and the BackPack headers. To do this, we

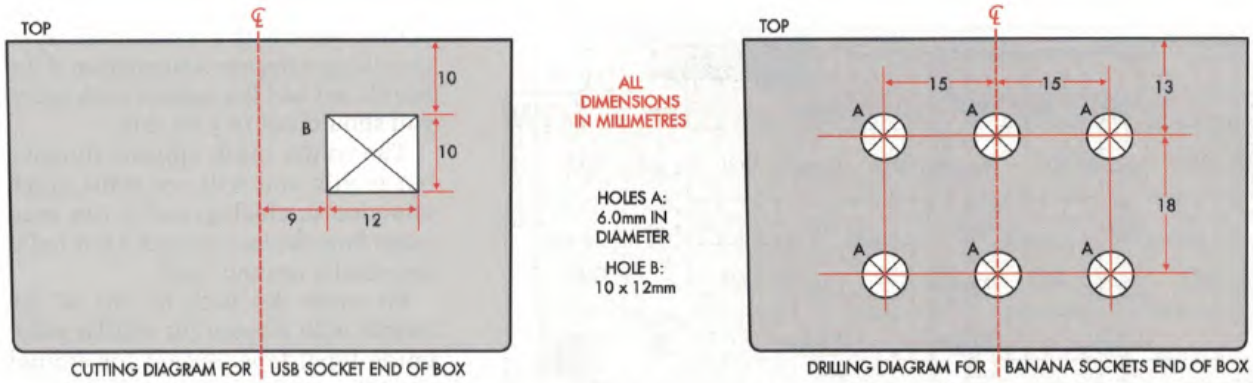


Fig.5: this shows the location and size of the cut-out for the USB cable, plus the hole locations and sizes for the banana sockets on the opposite side of the case. If you have a USB lead with a large housing, you may need to enlarge its hole. A round (drilled) hole is easier to make, but will not look as neat.

remove the individual pins from the plastic spacer strip, which you can do using small pliers.

With the boards held together in the stack, simply slot the pins through the PCB holes into the female header on the Micromite BackPack, one at a time.

Once you have confirmed that everything will fit together, solder the header pins to the PCBs, ensuring that enough solder is applied to wick down the stack into the bottom PCB of the pair.

This can be assisted by squirting a little flux paste into each hole before inserting the pin.

Alternatively, if you have no plans to remove the PCBs from the BackPack, you could omit the female headers and solder male headers directly to the BackPack.

Then, after mounting the resistor and capacitor/inductor PCBs, solder the headers to these two PCBs as well.

You may need longer pins to do this, or you may choose to run short lengths of wire between the two boards instead.

USB socket

For our prototype, we simply made a cut-out in the side of the box to allow power to be supplied to the BackPack using a standard USB cable with a mini Type-B connector. Its location is shown in Fig.5. This hole will allow most USB-mini plugs to pass through the side of the box and directly into the Micromite's USB socket. It may need to be enlarged if your USB lead has an unusually large plug.

An alternative that we have used on some projects is to fit a DC barrel socket; its wires are run back to the 5V and GND connections. See Fig.6 for how to wire such an arrangement. You will need to solder the wires to the pins on the capacitor/inductor board, as this connects to the header on the BackPack board.

Note that such a DC jack must be installed near the lid of the Jiffy box as the PCB extends nearly the full width of the bottom of it. Altronics (P6701) and Jaycar (PP1985) both carry USB to DC plug leads made up. Or you could use a regulated plugpack with 5V output and the correct tip polarity, to match the socket wiring.

Banana sockets

You might have noticed that there is not much space in the Jiffy box; thus, we've had to use low-profile banana sockets for the six test connections.

The locations of their mounting holes, on the opposite side to the USB power cut-out, are shown in Fig.5.

Once fitted, the sockets are simply free-wired back to their respective pads on the PCBs. We suggest mounting the sockets in the enclosure first, to test that they do not foul the PCBs.

Once this is done, solder short (5cm) leads to each socket, then solder them to the respective pads on the PCBs. CON1 is for the resistance connections, CON2 for capacitance and CON3 for inductance. The LCD shows their values in this order from top to bottom, so the sockets should be wired accordingly.

You may find it easier to remove the PCBs from the stack while soldering the leads. None of the parts are polarised, so it doesn't matter if you swap the wires to the pairs of sockets.

Micromite setup

There are two ways to load the software on the Micromite; the easiest is to simply load the "RCLBOX.HEX" file directly onto the chip using the onboard Microbridge or a PIC programmer such as a PICkit3 or PICkit4 (or purchase a pre-programmed chip, which is equivalent to doing this).

The alternative is to load the Micromite with MMbasic, then configure it and upload the BASIC source code over the serial terminal.

This is the required approach if you wish to customise the way the RCL Box works.

To do this, assuming you have a new Micromite (we're using MMBasic version 5.4.8), first open the "library.bas" file (extracted from the download

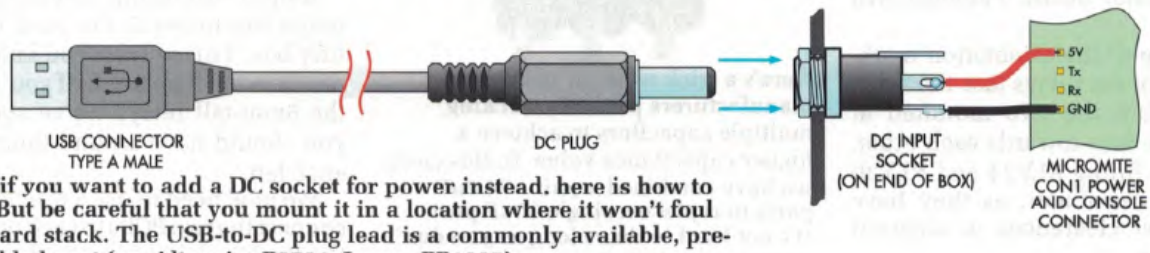


Fig.6: if you want to add a DC socket for power instead, here is how to do it. But be careful that you mount it in a location where it won't foul the board stack. The USB-to-DC plug lead is a commonly available, pre-assembled part (eg, Altronics P6701; Jaycar PP1985).

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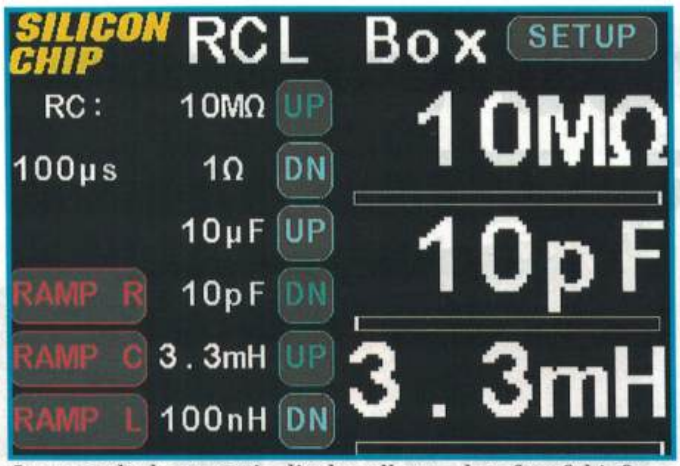


Screen1: the larger 3.5in display allows a lot of useful information to be displayed by the Micromite. At right are the three output parameters, displayed adjacent to their respective banana sockets. The values can be changed by a simple tap up or down, via a slider or automatically ramped by the software.

Screen2: pressing the SETUP button opens the Limit Settings page. Soft limits can be set to avoid non-useful or dangerous test values. Further settings can be found by tapping on the RAMP or DISPLAY buttons, while STORE saves the current setting to non-volatile flash memory.

package for this project, available on our website) and upload it to the Micromite (eg, using MMedit).

Then type "LIBRARY SAVE" at the Micromite console and press enter. Next, type "WATCHDOG 1". After pressing Enter, the Micromite should restart and the screen will clear. The terminal should display:

```
Watchdog timeout
Processor restarted
ILI9488 driver loaded
```

You can then run the command "GUI TEST LCDPANEL"; you should see circles appearing on the LCD. Press Ctrl-C to end the test.

Next, run "OPTION TOUCH 7,15" to enable the touch driver. Then run "GUI CALIBRATE" and complete the calibration sequence.

If you like, you can run "GUI TEST TOUCH" to confirm that the display and touch panel are working correctly together. Ctrl-C ends this test program too.

At this stage, the display is configured and the main BASIC program can be loaded. Open the "RCL Reference Box.bas" file, send it to the Micromite and run it. The AUTORUN flag is automatically set, so the software will start up when powered in future.

The software as loaded now is the same as what you would get from the HEX file; the remaining steps are settings and configuration within the Programmable RCL Box.

Finishing touches

If you have not already done so, fit the acrylic lid to the LCD by removing the four machine screws. Place the 1mm spacers over the holes and thread the machine screws through the acrylic panel and into the tapped spacers.

Note that the acrylic lid piece is not symmetrical; if it appears that the PCBs behind are sticking out the side, you may have it the wrong way around. As a hint, the end of the Micromite BackPack with the USB socket goes to the end with the wider-spaced holes.

Slot the stack into the case and secure the lid with the four screws that came with the Jiffy box.

Configuration and use

When powered up, a splash screen appears, followed by the main operating screen (Screen1). This is where the resistance, capacitance and inductance values are controlled.

In a large font along the right-hand side are the currently selected resistance, capacitance and inductance values. There are three ways that these values can be changed.

Firstly, the slider beneath each value can be used to make quick, coarse changes. You should have no trouble picking the exact value needed, but the up and down buttons to their left are better to make fine changes.

To the left of the up and down buttons are the soft limits which can be set. These allow the output values to be restricted if this is desired. Note that the up and down buttons are greyed out when the values are at their soft limits, warning you that you are at the extreme values.

At bottom left are the ramp controls, which can be used to step the outputs automatically. They are red when the ramp is inactive, turning green when activated. The ramps make use of the minimum and maximum soft limits as their range.

Above this is a small numerical display, which indicates a characteristic time or frequency based on a selected combination of the currently enabled resistance, capacitance and inductance.

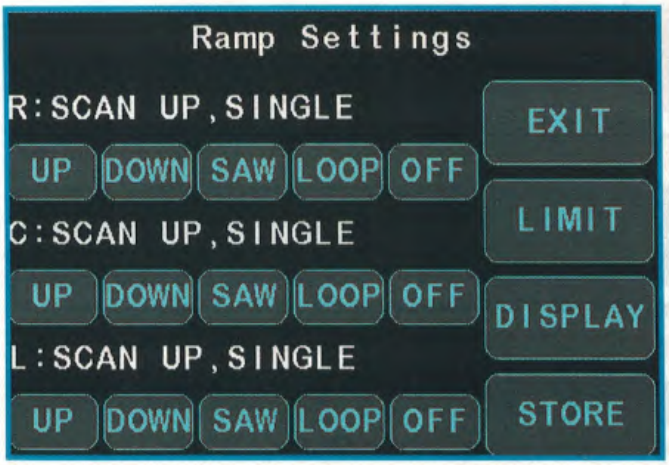
The "Setup" button at top right changes to the first of three pages for altering settings (Screen2). This allows the soft limits to be altered, with up and down controls for the minimum and maximum values of each range.

Any changed settings are made active immediately, but are not automatically saved to flash. This is done by the "Store" button, which ensures that the current settings are saved for use at power-on.

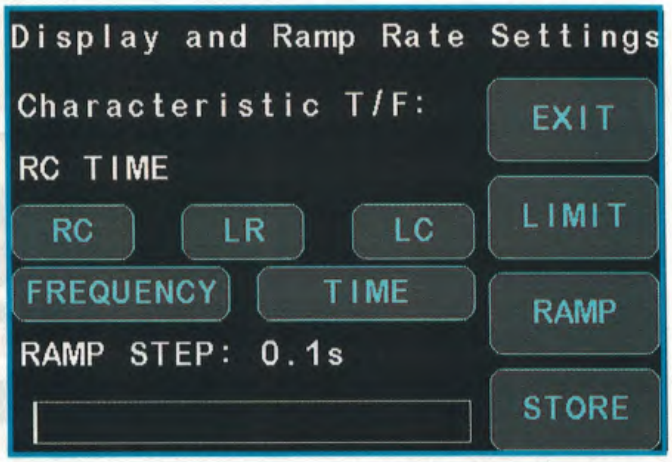
This has been done to minimise wear and tear on the internal flash memory and also provides an opportunity for settings to be tested before saving. If you change the settings to something you don't like, then a simple power cycle will reload the last saved values.

Pressing the "Exit" button returns to the main control page; this and some of the other buttons are present on more than one page to allow ease of navigation.

Pressing "Ramp" opens a page for the settings that control the ramp modes (Screen3); a setting for ramp



Screen3: the RAMP setting page controls the automatic ramp modes. These can be set to up, down or sawtooth with the option to perform a single or repeated ramp. There are individual settings for resistance, capacitance and inductance; thus, you can ramp resistance up and capacitance down simultaneously if that is what is needed.



Screen4: the DISPLAY page contains the setting for what characteristic time/frequency should be displayed. A choice of either LC, RC or LR combinations can be chosen, with either time constant or frequency being available as further options. The step time for the ramp modes is also chosen by the slider along the bottom of the page.

rate is found on the "Display" page (Screen4).

There are settings to ramp up, down and in a sawtooth pattern ("Saw"), which alternates between up and down.

The ramps can also be set to loop continuously or not ("Off"). The current setting is displayed in a friendlier fashion above the buttons.

If an output is set to ramp up but not loop, it will ramp up to its maximum and then stop. The next time it is started, it will reset to the minimum and ramp up again. This simplifies repeated tests.

The Display page includes the ramp step time; this can be set from 0.1s to 10s in 0.1s intervals by dragging the slider along the bottom of the page.

The final setting at the top of the Display page is the characteristic time/frequency, which controls what is displayed at the top left of the main page. There is a choice of RC, LR or LC combinations, and the characteristic time constant or frequency can be selected.

Of course, these may not match the operation of your circuit as not all circuits operate at their characteristic time constant, but they are a useful thing that the processing power of the Micromite can add.

BASIC code

In case you wish to delve into the operation of the BASIC program deeper, we'll explain a little bit about how it works.

After a handful of OPTIONs are set near the start, several colour values are defined. If you wish to change the feel of the interface, changing these colours is an easy way to do it.

The output values and relay images list the available values in pairs of arrays. One contains a list of the output values as floating-point numbers; these are the RVALUE, CVALUE and LVALUE variables.

The RIMAGES, CIMAGES and LIMAGES arrays contain nominal 16-bit values which describe the bit pattern which is output to the relays.

In the case of the capacitor and inductor images, these are combined with a simple addition to allow the data to be combined for simultaneous latching.

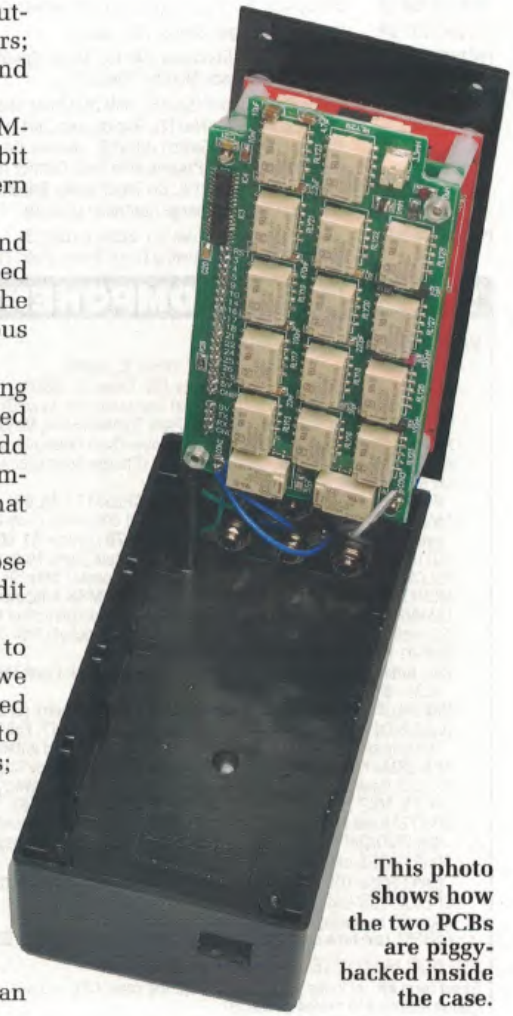
There would be little point changing the image arrays unless you reworked the circuit itself, but you could add extra resistance values by using combinations of more values than what we have.

Note that these lines are very close to BASIC's 255 character limit, so edit them with care.

Most of the remaining code is to create the user interface. While we often complain about how bloated software can be at times, it's nice to have an easy-to-use set of controls; it's just unfortunate that it takes so much code to do so!

The five subroutines starting with RELAYINIT perform the interfacing to the shift registers.

If, for example, you were interested in interfacing these boards to another microcontroller such as an Arduino or even a Raspberry Pi, then we suggest looking at these subroutines to understand how to interface and check the schematic to know what pins need to be connected. SC



This photo shows how the two PCBs are piggy-backed inside the case.

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PIC12F675-E/P	Courtesy LED Light Delay (Oct14), Fan Speed Controller (Jan18)
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PIC16F1507-I/P	Wideband Oxygen Sensor (Jun-Jul12)
PIC16F88-E/P	Auto Headlight Controller (Oct13), Motor Speed Controller (Feb14) Automotive Sensor Modifier (Dec16)
PIC16F88-I/P	Cyclic Pump Timer (Sep16), 60V DC Motor Speed Controller (Jan17) Pool Lap Counter (Mar17), Rapidbrake (Jul17) Deluxe Frequency Switch (May18), Useless Box IC1 (Dec18) Remote-controlled Preamp with Tone Control (Mar19) UHF Repeater (May19), Six Input Audio Selector (Sept19) Universal Battery Charge Controller (Dec19)
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$15 MICROS

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PIC16F1459-I/SO	Four-Channel DC Fan & Pump Controller (Dec18)
PIC16F877A-I/P	6-Digit GPS Clock (May09), 16-bit Digital Pot (Jul10), Semtest (Feb12)
PIC32MM0256GPM028-I/SS	Super Digital Sound Effects (Aug18)
PIC32MX170F256D-501P/T	44-pin Micromite Mk2 (Aug14), 4DoF Simulation Seat (Sept19)
PIC32MX170F256B-50I/SP	Micromite LCD BackPack V1-V3 (Feb16 / May17 / Aug19) GPS Boat Computer (Apr16), Micromite Super Clock (Jul16) Touchscreen Voltage / Current Ref. (Oct16), Deluxe eFuse (Aug17) Micromite DDS for IF Alignment (Sept17), Tariff Clock (Jul18) GPS-Synched Frequency Reference (Nov18), Air Quality Monitor (Feb20) RCL Box (Jun20)
PIC32MX270F256B-50I/SP	ASCII Video Terminal (Jul14), USB M&K Adaptor (Feb19)
PIC32MX795F512H-80I/PT	Maximite (Mar11), miniMaximite (Nov11), Colour Maximite (Sept12), Touchscreen Audio Recorder (Jun14)

$20 MICROS

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dsPIC33FJ128GP802-I/SP	Digital Audio Delay (Dec11), Quizzical (Oct11) Ultra-LD Preamp (Nov11), LED Musicolour (Oct12)
PIC32MX470F512H-I/PT	Stereo Echo/Reverb (Feb 14), Digital Effects Unit (Oct14)
PIC32MX470F512H-120/PT	Micromite Explore 64 (Aug 16), Micromite Plus (Nov16)
PIC32MX470F512L-120/PT	Micromite Explore 100 (Sept16)

$30 MICROS

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Loewe's 1927 OE333: simplicity itself

By Ian Batty

Talk about a minimalist radio set! Did they go a bit too far in stripping it back to essentials?

Known as the Ortsempfänger (local receiver) OE333, this set must be the ultimate in electrical simplicity for anything short of a crystal set. At the time this set was released in the late twenties, radios were taxed based on the number of valves. So there was an incentive to keep the valve count down, as long as it didn't hurt performance too much.

So they thought: why not combine several electrode assemblies into one "valve" for a compact, low-cost radio? That's just what young Baron Manfred von Ardenne did. Obtaining a patent at the age of 15 and dropping out of high school, he sold the patent to Dr Sigmund Loewe and took up work with him.

Loewe and his brother David had established Radiofrequenz GmbH in 1923 in Berlin, and Loewe's company began releasing 3NF-based sets in 1927.

Valves of the day were expensive; the 3NF more so. But Loewe offered a repair service that would replace blown filaments and restore "as new" performance. In practice, both filaments were always replaced.

While the 3NF is probably the best known of Loewe's "multi-valves", they also released the 2HF dual tetrode and the metal-shielded WG36, containing an RF pentode, triode local oscillator and pentode IF amplifier.

It would have been possible to put just the valve assemblies into the envelope, but von Ardenne and Loewe decided to put all minor components in as well: two anode load resistors, two grid resistors and two audio coupling capacitors.

While this was a practical construction, the use of only six connecting

Front view of the OE333. "Lautsprecher" is German for "loudspeaker".

Top-to-bottom, left-to-right: the Kleinempfänger DKE38 (July 2017), Loewe OE333 and Grebe Synchrophase (July 2016 & February 2018).

pins did mean that all signal coupling would have to be at audio frequencies, as no tuned circuits could be placed anywhere between the input connection and the output.

A close look reveals the six minor components individually encased in glass sleeves, and presumably evacuated via sealed-off pips. This would be necessary to prevent any escaping gaseous material from these components compromising the near-perfect vacuum that the valve sections needed to continue operating.

How it works

Two of the triode valves (stages 1 and 2) are designed for high-gain operation, while the third is designed for driving the loudspeaker. The filaments for stages 1 and 2 are wired in series across the 4V filament supply; stage 3 has the full 4V applied. All three use "dull emitter" thorium-coated wire.

The valve characteristics are plotted in Fig.1 (for stages 1 & 2) and Fig.2 (stage 3). Notice that the anode current (Anodenstrom) is shown in microamps (10^{-6}A) for stages 1 & 2, so this is a very low-current valve.

But the amount of gain you can get from a triode is based on its amplification factor (MU), modified by the anode load value, and this is principally the valve's anode resistance and the load resistor, both in parallel with the following stage's grid resistor.

Despite its anode current of only tens of microamps, the amplification factor exceeds 50. There is a somewhat similar RETMA valve, the octal IH5G/GT.

The 3NF was mainly used in radios; however, one ingenious company used it in a clockwork-motor radio station identification machine!

The radio circuit is simplicity itself – see Fig.3. Stage 1 works as a grid-leak demodulator. It is biased via the G1 pin, set at 1.5V by a battery tapping. Varying this, I was able to reduce the set's gain, but no circuit shows such a feature, so volume control was achieved by swinging the antenna circuit coils apart or together, to vary coupling.

The antenna circuit, as with all well-designed receivers, contributes to performance: at 600kHz, there was a voltage step-up of almost 13 times between primary and secondary.

The tuning capacitor is straight-line capacitance, so stations crowd together at the top of the band. Like the DKE38 Kleinempfänger I reviewed in the July 2017 issue (siliconchip.com.au/Article/10728), it uses a solid plastic dielectric, giving a compact design.

There are no bypass capacitors anywhere on the set (relying on the low impedance of batteries instead). I did experience feedback with untidily-placed test leads at one point.

Stage 1 capacitively-couples demodulated audio to stage 2. Stage 2 is internally biased by its grid resistor returning to ground.

As the filament is at the top of the series string, this puts some -2V of bias on the valve. Stage 2 capacitively couples to output stage 3, which picks up -7.5V external bias via its grid resistor from pin G3.

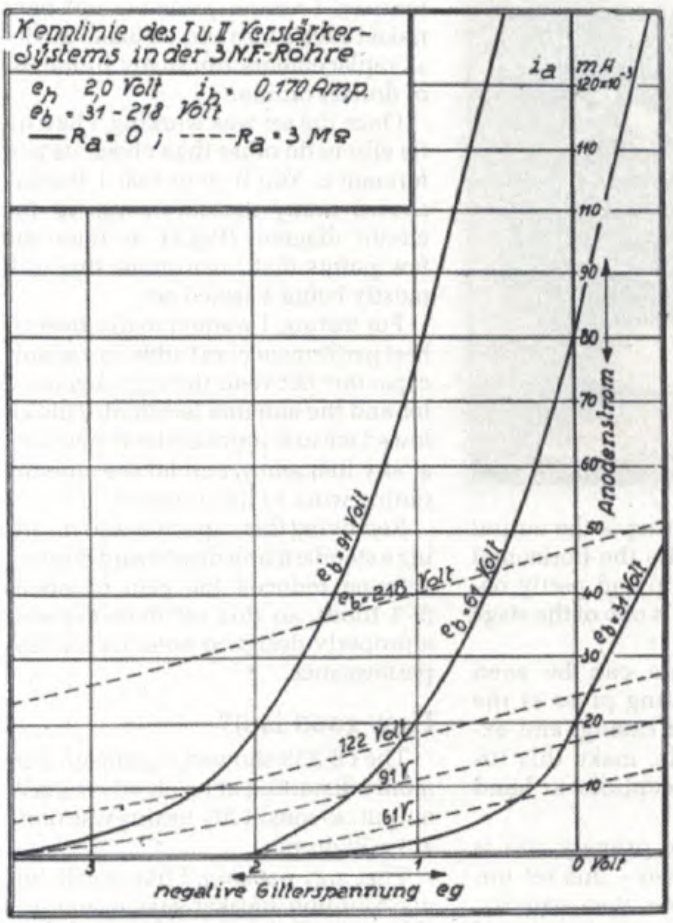


Fig.1: plot of the 3NF valve characteristics for stages one and two.

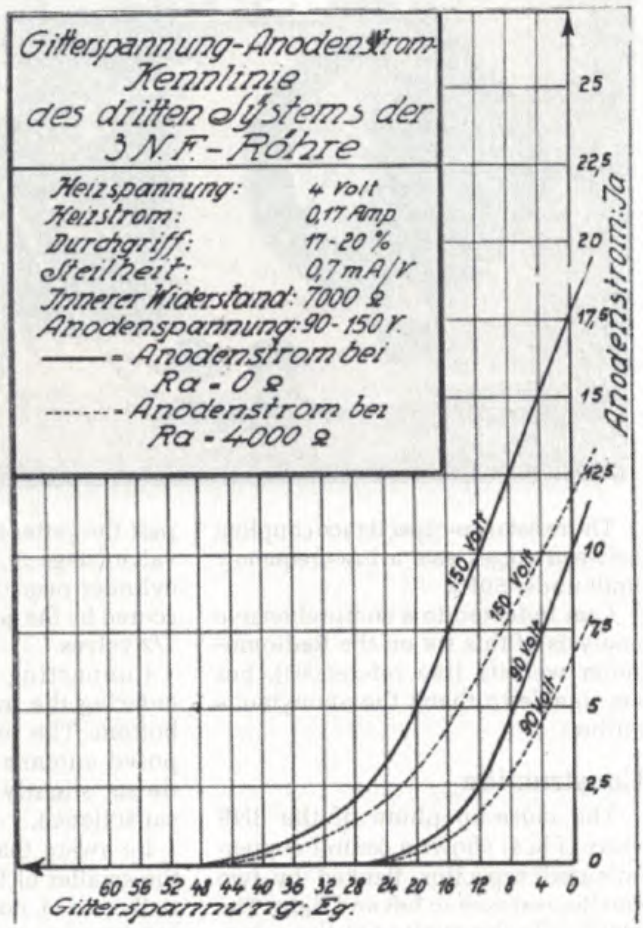

Gitterspannung-Anodenstrom-Kennlinie des dritten Systems der 3 N.F.-Röhre
Heizspannung: 4 Volt
Heizstrom: 0,17 Amp
Durchgriff: 17 - 20 %
Steilheit: 0,7 mA/V
Innerer Widerstand: 7000 Ω
Anodenspannung: 90 - 150 V.
—— = Anodenstrom bei Ra = 0 Ω
------ = Anodenstrom bei Ra = 4000 Ω
Anodenstrom: I_a
150 Volt
150 Volt
90 Volt
90 Volt
60 56 52 48 44 40 36 32 28 24 20 16 12 8 4 0
Gitterspannung: E_g

Fig.2: 3NF valve characteristics for stage three.

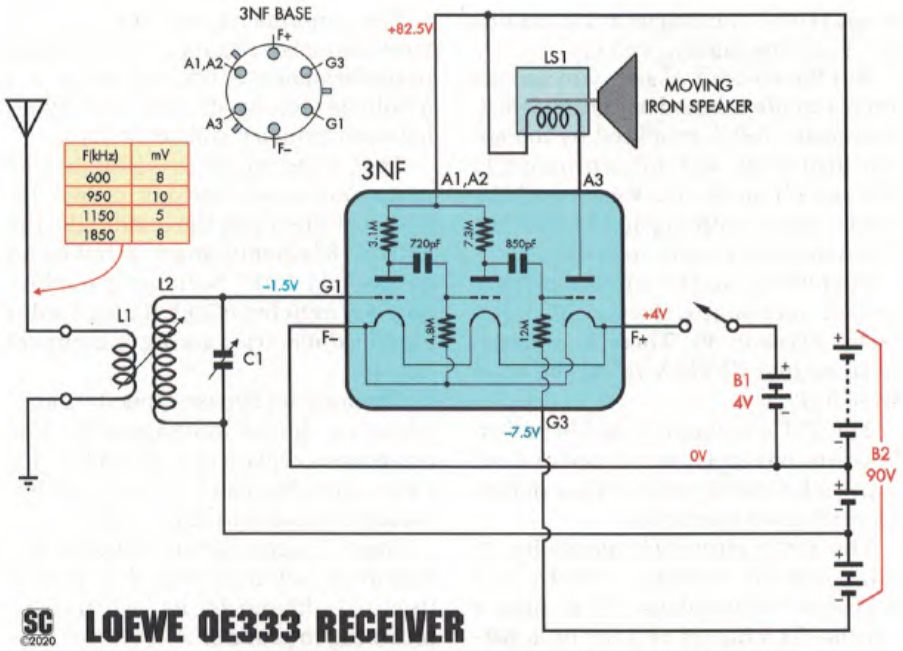
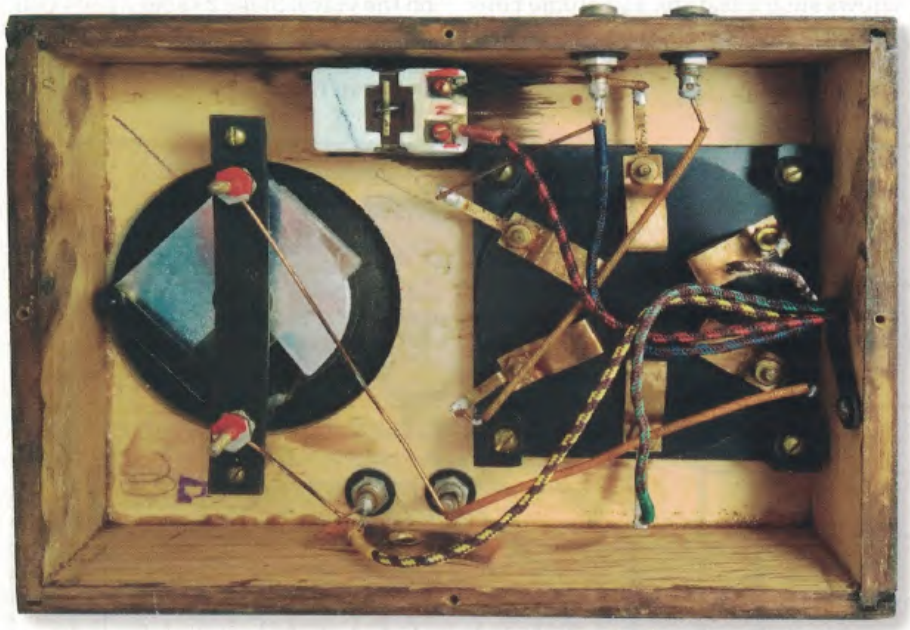


Fig.3: circuit diagram for the Loewe OE333. As reinforced by the photo of the underside below, this is an extremely simple radio.



The resistance-capacitance coupling between stages sets a low-frequency limit under 50Hz.

I am indebted to a comprehensive analysis of this set on the Radiomuseum website (see references), but am unable to thank the anonymous author.

Construction

The close-up photo of the 3NF valve (Fig.4) shows a central copper-coloured capacitor, flanked by two smaller resistors to left and right. The metal cylinder starting at the centre of the picture and extending upwards past the getter silvering is the output valve (stage 3), while the horizontal cylinder near the top and partly obscured by the getter is one of the stage 1/2 valves.

Connecting leads can be seen entering the mounting press at the bottom. The timber casing, and exposed antenna coils, make this little set slightly susceptible to hand capacitance.

Be aware that the primary coil is the smaller of the two – this set initially tuned no lower than 850kHz, but tuned correctly once I swapped the two coils over.

I used an Amplion cone speaker for testing, but any high-impedance horn or cone speaker will work. You could also use a conventional moving-coil speaker with a transformer with around 4kΩ primary impedance.

Clean-up

This set was in excellent cosmetic condition, having been bought at auction from the Historical Radio Society at RadioFest 2019 in Canberra.

Electrically, it is some 90 years old, and I was a little apprehensive about the 3NF's condition. Applying power (very carefully) didn't seem to get much response.

Cleaning up the contacts helped a bit; however, performance still seemed lacking. But the set came good after maybe half an hour of operation. This can happen with old valves, especially with thoriated filaments.

The thorium coating is only a few atoms thick and can degrade over time. Typically, it recovers in operation. While the recovery can be sped up by applying over-voltage to the filament, thankfully I did not need to do this. Frankly, I would probably not have risked such a rare and valuable device as replacements run many hundreds of dollars online.

Once the set was working, I had little else to do other than check its performance. You'll note that I haven't shown many measurements in the circuit diagram (Fig.3), as there are few points that I can probe due to it mostly being a sealed set.

For testing, I wanted to discover its best performance, so I added a variable capacitor between the signal generator and the antenna terminal. This allowed me to achieve optimal matching at any frequency, and let the antenna tuning work to its optimum.

Removing this capacitor and inserting a standard broadcast-band dummy antenna reduced the gain by about 2~3 times, so this set does demand a properly-designed antenna for best performance.

How good is it?

The OE333 showed significant harmonic distortion at levels above 5mW output, so sensitivity testing was done at 1mW output.

That may not sound like much, but my Amplion speaker gave a comfortable volume level in the workshop during testing.

The tuning range ran from 546kHz to 2350kHz, evidence of a large capacitance ratio (about 16:1) in tuning capacitor C1. Unlike a superhet, the antenna circuit does not need to track with any other circuit (such as a local oscillator), so it made no sense to add the expense of a trimmer that would have only reduced the maximum tuneable frequency.

Sensitivity varied with tuning, the best being 5mV at 1150kHz and the worst being 10mV at 95kHz: see the table in the circuit diagram (Fig.3) for more details.

Selectivity also varied: ±6kHz at 600kHz, ±14kHz at 900kHz, ±18kHz at 1150kHz and ±25kHz at 1650kHz, This variation in bandwidth is not unexpected for a single tuned circuit, but does permit more than one station at a time to be heard towards the upper end of the band.

Audio performance was only fair. For a 400Hz signal at 1mW output, total harmonic distortion (THD) was 6%; at 5mW, it rose to 10%, and clipping occurred at 10mW output, with 20% THD.

As noted above, broad selectivity allowed a few stations near the top end of the band to overlap, confirming the limits of any radio which only has antenna tuning. Unlike the DKE38, the OE333 could not take advantage of regeneration to improve its selectivity.

There were regenerative, mains-powered, dual-band versions of this set: Loewe's EB100W and R645W, among others. These took up an unused connection to the V1 anode, brought out through the envelope and tucked up inside the hollow of the press (stem) that supports the internal elements.

It would be fascinating to compare these for both sensitivity and selectivity, given the DKE38's impressive performance.

The OE333 is also nowhere near as good as the Grebe Synchrophase (July 2016: siliconchip.com.au/Article/10016 and February 2018: siliconchip.com.au/Article/10977), but then, almost no radios of the era can match it in performance. Remember that the five-valve Grebe used state-of-the-art neutralised RF amplifiers and audio coupling transformers, that together resulted in the voltage gain of a six-valve set.

The Synchrophase needs just 35µV of signal for a 1mW output. The Loewe, with no RF amplification, needed almost 230 times the same RF level to achieve the same 1mW output level.

But add in the Grebe's extra two valves (type 01A, with a maximum amplification factor of eight each), and two audio transformers (gain of three each), and my back-of-the-envelope calculations put a hotted-up Loewe on par with the Grebe.

Consider that I only had to throw about 10m of wire out of the workshop door and onto the carport to bring in 774 ABC Melbourne (about 60km away) at an acceptable listening level down here on the Peninsula. Radio National and five other metropolitan stations also came in at usable levels. A proper long-wire antenna would bring up all local stations well.

No-one with any sense of history (or of preserving value) is going to "improve" a classic set like this one, so let's take it for what it is. It's a milestone in radio history. Not only does it perform creditably for such a simple design, but its compact form with exposed components would also have made it a 'pride of place' addition to the modern household of 1927.

Forget those boring sets with their large, imposing, closed cabinets and dial after dial after dial to twiddle and misadjust.

This set is an example of the 'steam engine effect'. Major parts of the mechanism are exposed to view. Even relative novices could point to the antenna coils, to the three-in-one valve, and not only recognise them, but maybe even say a few words to onlookers to show that they were au fait with the wonder technology of the age.

Put this marvel of 1920s engineering next to any old timber-cased radio of the day, and I'm pretty sure I know which one would attract the most interest.

Would I buy one?

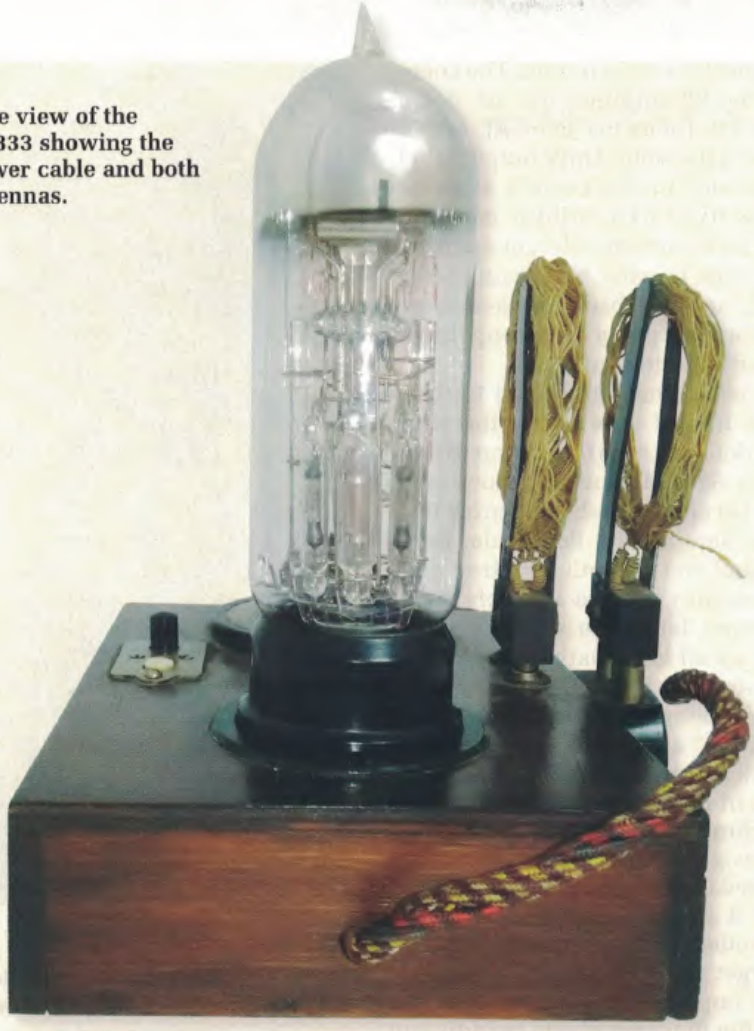
I might. Expect to pay at least $800 locally, more online/overseas. I'm thinking of saving up a bit of money and seeing what turns up. It would be so cool.

Loewe OE333 versions

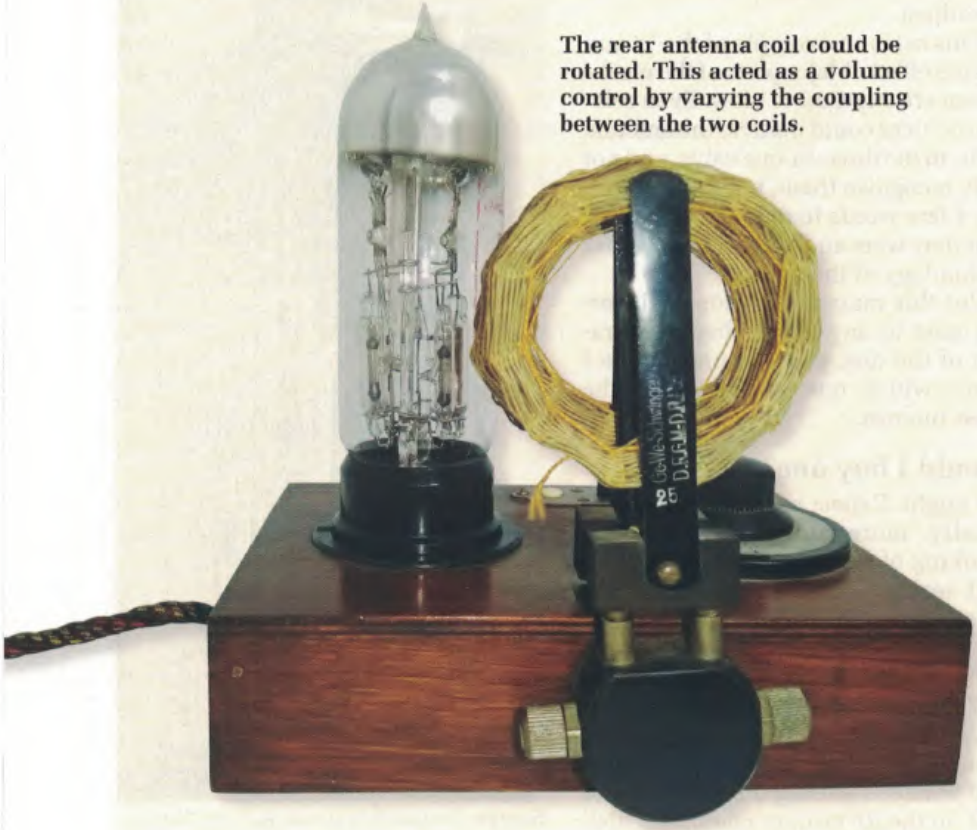
There are many similar radios from several manufacturers, including mains-powered regenerative versions, and versions adding the dual-tetrode 2HF in the RF circuit. Search for 3NF

Fig.4: interior of the 3NF valve, showing the stage 1 & 2 triodes at top (horizontal cylinders) and vertically orientated output triode in between.

***Source:* lampes-et-tubes.info/rt/rt175.php**



Side view of the OE333 showing the power cable and both antennas.



The rear antenna coil could be rotated. This acted as a volume control by varying the coupling between the two coils.

at Radiomuseum (see link below) for more information.

Special handling

The battery leads on this one were flexible enough for my testing, but you should examine them and treat them with care. They can become brittle with age.

Be alert for the visually-identical 3NFB. Although it also uses a 4V filament supply, all three filaments are wired in series. Otherwise, it appears to work identically to the 3NF.

I was super-cautious about the filament voltage, but so long as you only apply the recommended 4V, you should have no dramas.

But be aware that thoriated filaments can take a little while to regenerate. There's more information on thoriated cathodes on page 93 of the February 2018 issue of SILICON CHIP in my article on the Grebe Synchrophase (siliconchip.com.au/Article/10977).

If you acquire one of these but get no useful output after maybe an hour of operation, or the HT current is a lot less than 3mA, first check that you have the biasing correct.

If all supply voltages are OK, you may consider revitalising the filament. I recommend that you be really sure of the need to do this, and that you research the process thoroughly before proceeding.

Conclusion

Special thanks to Jim Easson of the Historical Radio Society of Australia (HRSA) for the loan of this rare and remarkable radio. Thanks also to Giorgio Basile of http://lampes-et-tubes.info for his superb website and the supply of the close-up photo of the 3NF. Not an HRSA member? Hop on to http://hrsa1.com and have a look around.

Further reading

- Tyne, Gerald E. J., Saga of the Vacuum Tube, 1977, Howard W. Sams, Indianapolis (pp446-450).
- Ernst Erb's Radiomuseum (http://radiomusuem.org) has heaps of circuits, photos and articles on the OE333 and other implementations of the 3NF and its cousins. There is also a very thorough two-part analysis (in German) of the 3NF:

siliconchip.com.au/link/ab23
siliconchip.com.au/link/ab24

- A stunning photo essay: http://lampes-et-tubes.info/rt/rt175.php SC

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Using NaOH in anodising aluminium

Firstly, thanks for a great magazine! I'm hoping you can help clarify something I am confused about regarding Phil Prosser's article "Anodising Aluminium at Home" (May 2020; siliconchip.com.au/Article/14423).

The article refers to etching the surface of the aluminium part to be anodised using sodium hydroxide (p33); however, this chemical is not listed in the "Here's what you need" table on page 27. Instead, it lists sodium bicarbonate.

I have re-read the article several times to try to clarify my confusion about sodium hydroxide. At first, I thought was another name for sodium bicarbonate; sodium bicarbonate is listed in the table and pictured but not used in the process.

However, a Google search indicates they are two different chemicals (sodium hydroxide is NaOH, whereas sodium bicarbonate is $NaHCO_3$). Can you clarify?

In another article, A Touchscreen Car Altimeter (May 2020; siliconchip.com.au/Article/14431), I noticed a typo on p70 in the first paragraph: Mosfet Q1 is mentioned instead of Mosfet Q2.

Anyway, keep up the great work! I love reading your magazine every month! (J. S., Goondiwindi, Qld)

● You are right that sodium hydroxide was accidentally left off the list of "what you will need" in the article. It is definitely a different chemical from sodium bicarbonate. You are also right about the typo in the Car Altimeter article.

Phil Prosser adds: sodium hydroxide (NaOH) is often used as a drain cleaner. We are using it to etch the aluminium. A solution of around 2% NaOH in water works a treat. It strips off existing anodising and cleans the surface. This is about a tablespoon full in a 500mL tub of water.

Sodium bicarbonate ($NaHCO_3$) is only there as a safety aid to clean spills. Throw it over spilt acid and it fizzes and neutralises the acid, allowing safer cleanup. This is commonly used in professional acid safety cleanup kits. It is super cheap in 500g bags from your local supermarket.

Reflow Oven Controller display glitch

I have built the DIY Reflow Oven controller project (April-May 2020; siliconchip.com.au/Series/343), and I have checked the build and wiring, but I have a problem. Upon power-up, the LCD shows a splash screen, then a page with the version number, then it goes blank.

Very occasionally, it continues to the screen where it shows a target temperature. I can rotate the encoder, and that temperature value goes up and down. If I press the EXIT button, it momentarily shows the screen to set the PID and other parameters, but only for a short time; then, the screen goes blank.

As far as I can see, the processor is still running because the LED continues to flash but until I cycle power, the screen remains blank. I do not have a programmer for the microcontroller. I have spent the weekend checking all connections, including between the LCD screen and CPU board.

Also, should the 32kHz oscillator be running? It is not, but I can see the 8MHz oscillator running with my scope, and I am assuming the probe (a high-quality Tektronics probe) is not loading the 32kHz crystal sufficiently to stop it oscillating. Since the secondary oscillator can be turned on and off by configuration, I have not chased this any further.

A quick look at the code seems to imply that if the event time has not changed, there is no update to the screen. Do you have any suggestions about what could be wrong? (C. M., Hallidays Point, NSW)

● The 32kHz crystal is not enabled by the software. It is provided for applications where the CPU board needs accurate long-term timekeeping, but this is not one of them. Based on what you have told us, it certainly sounds like the microcontroller is operating correctly.

Our original thought upon hearing about this problem was that it was an intermittent connection between the CPU board and display, but you say that you have checked those connections thoroughly.

That leaves us with the thought that your LCD screen has marginal timing specifications. What puzzles us is that the display updates are all handled identically by the microcontroller; it merely dumps the screen buffer to the display. The fact that it goes blank suggests that it may be spuriously resetting, but we don't know why that would happen.

We suggest that you try a different LCD module, as it seems that part may be acting up.

H-field Transanalyser panel meter substitute

Thanks for the articles on the H-field Transanalyser for AM radio testing (siliconchip.com.au/Series/344); I am going to build it. I have repaired several transistor radios, but my signal generator is not calibrated. I always wanted to measure sensitivity to see if the radio was performing normally.

I have had to go to a few places for the ICs; some equivalents (if there are any) would have helped. I have a 0-1mA meter but it is 100Ω, not the 200Ω of the specified Jaycar meter. Is there enough adjustment range in the 500Ω trimpot or should I reduce the value of the 510Ω series resistor, or just buy the Jaycar meter? (J. G., Bendigo, Vic)

● Dr Holden thinks that your meter would probably adjust correctly with the trimpot that is there. You could always put a 100Ω resistor in series, or fit a 1kΩ trimpot if you can't calibrate it. Things are always more predictable with the correct part though; the geometry might also be a problem, so

probably the safest advice is to get the specified part.

Commercial PCBs and tin-lead solder

I am making the H-field Transanalyser (May-June 2020; siliconchip.com.au/Series/344). It has been a while since I built one of your designs. Do your current PCBs and components require lead-free solder or will they work with lead/tin? (J. G., Spring Gully, Vic)

● Our PCBs can certainly be used with tin/lead solder, and virtually all components are designed to work with either tin/lead or lead-free solder. We expect that most of our readers are still using tin-lead solder as it is easier to work with.

Generally, tin/lead solder can be used on PCB pads which are tinned with lead-free solder. The reverse is not necessarily true; PCBs with a layer of tin-lead hot-air levelled solder (HASL) are not suitable for lead-free soldering. This is because the lead will mix into the lead-free solder and form of a less stable alloy, possibly leading to failed solder joints (and of course, the result will not be lead-free either).

We don't specify lead-free HASL on the boards that we sell because it's an additional cost and we think few of our readers will be using lead-free solder. However, given the popularity of lead-free solder, especially in Europe, we suspect that most of the boards we get are lead-free anyway. But we can't guarantee it.

You can get lead testing kits if you want to find out for sure. Kits intended for testing for lead in paint are readily available although expensive unless you purchase a large quantity (eg, $40 at Bunnings for a two pack!). If you shop around a bit and buy a larger quantity, you can find test kits for around $5/test.

Can magnetic surveys locate crashed aircraft?

I read with interest your article on Underground Mapping etc, from the February 2020 issue (siliconchip.com.au/Article/12334). Most importantly, I noticed Fig.11 on page 16, "French airborne magnetic survey from a drone."

Do you have any idea whether an aeroplane that has gone missing in a rainforest could be found with this technique? I refer to the infamous VH-MDX which disappeared on the 9/8/1981. Here are some links:

https://vhmdx.com.au/
siliconchip.com.au/link/ab37
siliconchip.com.au/link/ab38

The aircraft has never been found, and the loved ones have never had closure. Could you put me in touch with someone who might have this equipment? (Dick Smith, via email)

● Dr David Maddison replies: I have written to ECA Group in France to see what they can offer. The small amount of ferrous metal from unexploded ordnance (UXO) that they are finding might be similar to what is to be found in a small plane, but the difference is that the UXO field mapped by ECA is small, and a drone can fly low and slow over the area.

Looking for a plane in a vast area of forest is a different matter because of the difficulty and time involved in flying low over the entire area with a drone.

I found an article about the US NOAA using a magnetic anomaly detector (MAD) to find WW2-era aircraft remains underwater (siliconchip.com.au/link/ab2v). But note that even when looking for much larger submarines, the MAD equipment has to come quite close to the sub to detect it as the disturbance in Earth's magnetic field is generally small.

PID controller based on a Micromite

I have been working on a smoker/BBQ draught controller using a Micromite LCD BackPack I obtained some time ago. This is my first major programming project. I have been using MMBasic, inspired by your Air Quality Monitor project (February 2020; siliconchip.com.au/Article/12337).

I found that reading through your code helped me a great deal with my novice code writing. I am still struggling with the PID bit.

You could understand my delight when I read of your current Reflow Oven Controller (April-May 2020; siliconchip.com.au/Series/343), incorporating PID in a very laggy system. The project is very similar to the one I am working on, except that mine will drive a servo.

I see from the article that the HEX code will be available on your website, but there is no mention of the source code. Is it possible that you could make the source code available for download? I wonder what language it was written in.

I hope you can help me with this. Also, can I suggest that an option to drive a servo be added to the project? (R. M., Ilkley, Qld)

● The download package for this project includes the source code. The project is written in C. It's fairly complex as it's built from scratch and incorporates the GUI code, display driver etc. See siliconchip.com.au/Shop/6/5411

The implementation of the PID system is built into the interrupt service routine (ISR), which may be hard to understand if you are not used to working with code in ISRs. You may find that due to the system not being linear, the PID parameters need to vary from low to high temperatures to give reasonable control. Phil Prosser's code massively increases the differential coefficient at lower temperatures.

Phil has also said that he will contact you and try to help with any problems that you run into.

Transformer for amp plus preamp combo

I want to build the Ultra Low Noise Remote Controlled Preamplifier and your Six Input Selector (March-April 2019; siliconchip.com.au/Series/333 & September 2019; siliconchip.com.au/Article/11917) from Altronics kits. I want to use this with multiple devices ranging from a PC, laptop, TV and radios in an office/workbench environment.

I have a pair of speakers rated at 50W each, 4Ω and would like to choose a suitable amplifier. I am thinking of either the 20W or 50W amplifier kits from Altronics; there is not much difference in the price. An important requirement is for a single transformer to power the input selector, preamplifier and amplifier modules.

Another option is the 12V 20W amplifier which could be powered by a 15V DC 150W switchmode power supply (Jaycar MP3187). I am uncertain of the effects of using a switch-mode power supply to power the amplifier with regard to interference/distortion, or if I need to include some additional circuitry to prevent possible interference. (G. F., Bondi, NSW)

● You could power the Compact 12V 20W Stereo Amplifier (May 2010; siliconchip.com.au/Article/152) from

the MP3187. Some switchmode supplies can inject noise, but most will work OK. If it does have any effect, you will notice it straight away as noise in the background with no input signal.

Note though that your speakers only have a moderate sensitivity figure of 89dB @ 1W, 1m. So 20W per channel may or may not be enough depending on your requirements.

Also note that the MP3187 is not suitable for powering the Preamplifier or Six Input Selector. Those projects are designed for the ±15V rails you would get from a 15-0-15V (or higher voltage) toroidal transformer with rectifier, filter and regulators.

We've published many amplifiers that could deliver 50W into 4Ω running from a small toroidal transformer (probably 18-0-18V or 20-0-20V). That same power supply could also generate the ±15V regulated rails needed to run the preamp and input switcher.

The 50W Altronics kit you mentioned is presumably their Cat K5120, which is a kit for our SC480 amplifier from the January 2003 issue. That would be a good choice for your speakers, although its fidelity is not stellar (it's just OK).

The specified 28-0-28V transformer may be hard to get, but a 25-0-25V would suit your speakers better anyway. You could use our Ultra-LD Mk.3 power supply board (September 2011; siliconchip.com.au/Article/1160) which is available as a kit from Altronics, Cat K5168.

That would let you power two SC480 amplifier modules plus the preamp and input selector from the single 25-0-25V transformer. You may need to add small heatsinks to the regulators, though.

Adjusting preamp mute return trimpot

I have just finished building your Ultra Low Noise Remote Controlled Preamp and am having a problem with the mute return feature. The end-stop adjustment trimpot VR4 is quite sensitive in that rotation in either direction will correctly stop the motor, but prevent the mute return feature from working unless backed off a little.

When the volume pot does return, it is always to a higher level than before muting. Also, intermittently pressing Mute causes the pot motor to be appearing to forward and reverse rapidly but remain in the same position. The clutch can be heard slipping. Do you have any suggestions? (J. C., Chelsea, Vic)

● The mute return feature relies on the clutch slippage and the increase in motor current while slipping compared to normal running without slippage. Sometimes, the clutch needs to be run in for a while so that the slippage current is consistent. Then the trimpot adjustment can be made.

The intermittent forward/backward rotation during mute sounds like electromagnetic interference causing the microcontroller to malfunction. You may need to add more capacitance or a ceramic 100nF capacitor across the motor terminals and at the PCB terminals. Also, ensure that the motor body is Earthed.

Difficulty using different touchscreen

Hello, I have built your Diode Curve Plotter (March 2019; siliconchip.com.au/Article/11447). I uploaded the sketch, but all I get is a white screen on the LCD. I have double-checked all the connections and polarity and component values. The 2.8-inch ILI9341 touchscreen has HSD028309 E6 written on the very bottom of the screen. Can you help? (D. W., Penrith, UK)

● The displays we use have TJCTM24028-SPI and 2.8 TFT SPI 240*320 v1.1 printed on the rear silkscreen. While some of our screens also have "HSD028309 E6" printed on the front, a Google search suggest that it could have one of several different controllers including the ILI9341, ILI9325, ILI9328 or HX8347.

Are you sure yours has the ILI9341? Even if it does, there may be some incompatibility between that display and the ones we have tested. We suggest that you find a source for the TJCTM24028 module; it's widely sold at various online marketplaces. If it still doesn't work with that display unit, then something else is wrong.

Vibration Triggered Switch not behaving

I have tried to build the (apparently simple) vibration-triggered Motion Sensing 12V Switch (February 2019; siliconchip.com.au/Article/11410) but with little success. I followed the P-Channel layout in Fig.1.

First, I tried to build it on stripboard, but the 12V output just stays on indefinitely. So I built a second one, assuming that I must have had an invisible short somewhere. The second attempt, also on stripboard, just did the same. It stayed on permanently.

So, I designed a big PCB, about twice the size of the stripboard circuit shown on p28. I kept the spacing between components nice and loose, to avoid any shorts. This third attempt just does precisely the same as the first two attempts. It stays on permanently.

Have you heard from anyone who has managed to get the circuit working? Has anyone mentioned any misprints or incorrect component values in the published design? (J. L., UK)

● We've had mostly positive feedback about this project, so we don't think there's a fundamental problem with the design. Our prototypes do work, too.

First, check the voltage between the Mosfet gate and source pins and check the Mosfet orientation. If the Mosfet is wired up incorrectly (drain/source swapped), it will always conduct. If the output is on with the Mosfet working normally, the gate/source voltage will be significant; close to the full supply voltage.

Assuming that's the case, there are two likely causes: a stuck-closed vibration switch or a 100µF capacitor that has too much leakage.

Probing the circuit is likely to trigger the vibration switch, so it's best to clip two small leads across its terminals, being careful not to short anything out, then connect those to a voltmeter. Power up the circuit and leave it alone. The voltage reading should ramp up. If it doesn't, the switch is stuck shut.

We found these switches to be quite easy to damage. You have to be very careful when soldering to avoid overheating the part and damaging it internally.

If the voltage is rising but it never reaches the threshold to switch the Mosfet off, then that points to a leaky capacitor. It's a bit tricky to measure this since some current will flow through the voltmeter; it's possible for the circuit to work correctly with the voltmeter disconnected, but not connected.

So it's best to use a voltmeter with a minimum input resistance of 10MΩ for checking this circuit. Some meters have voltage-reading modes in the

gigohms, and these are the best ones to use for such a test.

DCC Decoder Programmer problem

I have not been able to get your DCC Decoder Programmer (October 2018; siliconchip.com.au/Article/11261) working. I am not using the DC boost Converter module but feeding 12V DC into the V_{IN} pin on the Arduino Uno module. I am using an oscilloscope to measure the output signals during operation.

I get the following output from the test program, "DCC_Programmer_Shield_V2.ino":

```
READ from CV1
Reading 1
CV:123
CVbar:64
Acks (out of 16):13
READ from CV1
Reading 1
CV:241
CVbar:128
Acks (out of 16):12
READ from CV1
Reading 1
CV:121
CVbar:0
Acks (out of 16):13
```

I am in lockdown and do not have another programmer, so cannot test program the DigiTrak decoder, but it is working as a control module controlling a train. (L. D., Wellington, NZ)

• It sounds like it's mostly working but the number of ACKs is higher than it should be (8). Try tweaking ITHRESHOLD value which is #defined on line 29 of the code.

Since you are getting too many ACKs, reduce the value. If you were getting 16 or 0 ACKs then I would suspect a more serious problem, but it seems that it is currently successfully detecting some ACKs but not others.

Test running the 800W+ UPS

I have finally gotten around to building the May-July 2018 800W+ UPS (siliconchip.com.au/Series/323). I loaded the Test sketch, which ran OK. However, even though the inverter does turn on and off at set intervals (checked with a multimeter and observed by the LEDs turning on and off, and it beeps), the serial feedback lists the inverter turn-off as "Fail". Does this matter? (N. M., Yass, NSW)

• We aren't sure what's causing this problem, but it could be a wiring fault. If you manually check that the inverter is running when the UPS is powered up, then it shouldn't matter.

The feedback is mostly used to avoid it getting into a confused state, but it only tries to change the state at startup and shutdown, so there's little chance of that occurring except at those times.

We suggest that you try to resolve it, but it certainly won't stop you test-running the UPS and getting it to a functional (if not perfect) state.

What is included in the SC200 kit?

I want to build your SC200 Amplifier module (January-March 2017; siliconchip.com.au/Series/308). If I buy the Altronics kit (Cat K5157), does it include all the high-quality components that you have specified? (F. C., Maroubra, NSW)

• We checked with the Altronics kits manager, and he told us that in their kits, they supply the exact parts we specify in our parts list.

They only make substitutions if they know the parts are identical or not critical (eg, changing MKT bypass capacitors to X7R ceramic, which we agree is OK).

In the case of the SC200, they informed us that there are few if any substitutions. All the transistors and capacitors in the audio path are identical to our original specifications, so you can be confident that the performance of a unit built from the kit will be very close to our prototypes.

Solar battery charger wanted

Can you design a DC-DC battery charger for a car/boat? A solar input would be useful. (M. Y., Auburn, NSW)

• We have published many battery chargers that run on DC, and some from solar panels. For example, the Solar MPPT Charger & Lighting Controller (February-March 2016; siliconchip.com.au/Series/296). That one suits 12V or 24V lead-acid or $LiFePO_4$ batteries and can charge at up to 10A.

If you supply more detail on the battery type, such as its chemistry, voltage and capacity, we may be able to find a more suitable charger for you.

Bypass capacitor value variation

I am building your Isolating High Voltage Probe for Oscilloscopes from the January 2015 issue (siliconchip.com.au/Article/8244). It uses four 100nF multilayer ceramic capacitors. I have some of these, which I checked, and their values are between 82-84nF. Will these be OK or should I obtain some with higher values? (W. F., Atherton, Qld)

• The typical tolerance for a multilayer ceramic capacitor is either ±10% or ±20%. It seems like yours are the latter as they would be out of spec for 10% parts.

We take the possible variation into account in the design, so the parts you have should be fine. Especially since the 100nF capacitors each have parallel 100µF capacitors to provide bulk energy storage.

Speed control for sewing machine

I need a speed controller for an older mechanical sewing machine. The mechanics are excellent, but the circa-80s electronics are dying (replacing caps, but what next?). The Husqvarna motor is a two-pole AC universal type rated for 70W at 220V 50/60Hz, 8000/7500 RPM.

The foot pedal speed controller that plugs into the machine's circuit board is purely a potentiometer – 90kΩ at startup, down to about 50Ω at full speed. Would your 230V/10A Speed Controller (February-March 2014; siliconchip.com.au/Series/195) be appropriate? Or is the motor too small for such a unit? (M. W., Main Creek, NSW)

• Yes, the 230V/10A Speed Controller for Universal Motors you mentioned would work, replacing the speed control pot (VR1) with the foot pedal pot. However, be careful as the speed controller operates at mains potential and so the wiring from the foot controller to the speed controller must use mains-rated wire, with the leads secured correctly.

Presumably, the foot pedal was designed for having mains voltage potential at the foot controller. You should double-check this, though. If it is in a metal case. that case should be Earthed.

You may wish to increase the gain of IC2a using a higher value than the

original 10kΩ resistor between pins 1 and 2, so that speed control is maintained under load. But most sewing machines do not have feedback speed control, so that may not be necessary. If it is, try using a 33kΩ resistor.

UV Light Box Timer has a dim glow when off

Hello, a while back I bought the HEX file and PCB pattern for the UV Light Box Timer (November 2007; siliconchip.com.au/Article/2422). Once the relay disconnects the lamps, I find there is still 28V supplied, making the lamps glow. I suspect that this small voltage is leaking through the 100nF capacitor that is in series with AC input and output. (R. C., Vilcabamba, Ecuador).

- You are correct in assuming the 100nF X2-rated capacitor is supplying current even though the relay contact is open. You could reduce the current to prevent the lamps glowing dimly by using a 10nF X2-rated capacitor instead.

This capacitor was included to protect the relay contacts from pitting each time the contacts open, due to sparking. The smaller value capacitor will also help prevent the pitting but to a lesser extent. The Light Box is only an occasional use item, so this should still be good enough.

Amplifier choke winding wire diameter

I am building a pair of stereo amplifiers using your High-Power HiFi Amplifier Module from April 1996 (siliconchip.com.au/Article/5015), from a Jaycar kit (Cat KC5201).

I already had two complete modules with two additional kits missing a few parts, including the choke coils. I managed to find two formers for the chokes, but I am a little confused about how to wind them

In the original article, the choke is wound with 24.5 turns of 0.8mm diameter enamelled copper wire, whereas the pre-made chokes in the kit are wound using 1mm diameter wire. Should I use 0.8mm wire as in the original instructions or 1mm?

I am also building an SC480-based amplifier from Altronics K5120 kits which use chokes hand-wound using 1mm enamelled copper wire. (D. F., Muswellbrook, NSW)

- The wire diameter used mainly determines the amount of current that the choke can handle before it overheats. You certainly can use 1mm diameter wire to wind the chokes for the April 1996 amplifier design instead of the specified 0.8mm diameter wire.

The decision to use 0.8mm diameter wire in the original design was probably so that the required number of windings would fit into the available former size. There are compromises when designing a choke. The wire needs to be of sufficient cross-sectional area to prevent fusing and overheating, but small enough for practical use. There is a wide variation of wire sizes that can be used in a given design.

Choosing a motor for an underwater camera

I am looking for a bit of technical advice for a project that I am undertaking for a local Education Centre. The project is essentially a 360° camera that looks underwater at high tide and allows the centre to bring ocean education to students. This will let them double their education time, as they are only able to take students out at low tide on their rock platform.

The project will be located along a small rock valley that is highly active with sea life, so we need it to have a stepper function so we can program a boundary for camera movements, to avoid the camera running into the rocks.

We don't know the weight of the rig yet, but it will need to be a 12V motor that can turn fast. A second motor will be used to lift and lower the camera. (I. T., Narrabeen, NSW)

- Motor selection depends on the amount of load the motor will be driving. Being a threaded-screw drive, the torque will be multiplied but the movement will be slower. A DC motor may be preferable to a stepper motor as it can run faster.

Also, the threaded screw drive will prevent movement when the motor is stopped. So the holding torque provided by stepper motors is not required.

The amount of movement can be determined by the period the motor is running, although it would probably be easier simply to limit the range of motion using microswitches. At a guess, motors such as the Jaycar Cat YM2716 or the larger YM2718 would be suitable.

Antenna designs for use with SDR

Congratulations on an excellent magazine. It gives me hours of reading every month, with a great balance of construction projects, technical interest and industry content. Even the ads are interesting.

I enjoyed the article on the Tunable HF Preamp for SDR (January 2020; siliconchip.com.au/Article/12219). My own experience living in a relatively unpolluted area, RF-wise, is that the best enhancement to any SDR is a decent antenna or two.

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Could antennas be the subject of a future article – either construction projects or enough background theory to enable readers to design and build their own?

Maybe a long wire and discone for starters. (D. P., Gisborne, NZ)

● Many thanks for your warm compliments regarding our magazine. Good to know that we're appreciated 'across the ditch'!

As you are no doubt aware, the antennas required for SDRs are really no different from those for conventional 'analog' receivers which cover the same frequency range. The only real difference is that SDRs generally have modest-to-poor input preselection, so that they generally benefit from an active preselector between their input and the antenna.

We have described many antenna construction projects in recent years, including the following, starting with the most recent:

- November 2015: A 5-element Antenna for better DAB+ Reception (siliconchip.com.au/Article/9394)
- October 2015: A 5-element Antenna for better FM Reception (siliconchip.com.au/Article/9137)
- February 2005: A really cheap Yagi antenna for UHF CB (siliconchip.com.au/Article/2982)
- January 2004: Antenna and RF Preamp for Weather Satellites (siliconchip.com.au/Article/3326)
- February 2001: A 2m Elevated Groundplane Antenna (siliconchip.com.au/Article/4248)
- June 1991: A Corner Reflector Antenna for UHF TV (siliconchip.com.au/Article/5918)
- January 1990: An Active Antenna for Shortwave Listening (siliconchip.com.au/Article/7317)
- March 1988: Antennas for the VHF and UHF bands (siliconchip.com.au/Article/7788)
- December 1987: Amateur radio in the VHF bands (siliconchip.com.au/Article/7855)

You will find some useful information on building your own discone antenna at http://siliconchip.com.au/link/ab25

But because discone antennas are not all that easy to build, you might consider buying a ready-made antenna or kit. One good option is from Tecsun Radios Australia: siliconchip.com.au/link/ab39

It comes in easy-to-assemble form, is made from stainless steel, covers the frequency range from 25MHz to 1300MHz and costs $160. SC

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Coming up in Silicon Chip

A switchmode replacement for 78xx series regulators

The 78xx series has been around for yonks and is still very useful today. But when there is a high input-output voltage differential, or you need a lot of current, linear regulators generate a lot of heat and have poor efficiency. This small board is a drop-in replacement for a TO-220 package linear regulator. It's up to 96% efficient, needs no heatsinking and has various output voltages from 3.3V to 24V.

Digital RF Power Meter

This project uses three low-cost modules, two ICs and a handful of passives to create a versatile RF Power Meter which can measure signals from 1MHz to 6GHz ranging from -60dBm to +35dBm. It is housed in a modestly-sized diecast aluminium case and powered via a USB cable.

Lidar, SODAR & ADCP

Radar and sonar have been around for a long time and most readers will be aware of them. But what about their counterparts, lidar and SODAR? Laser-based lidar systems are becoming more common, being used for mapping areas or for autonomous vehicle obstacle avoidance. SODAR is used for wind profiling at places like airports, while ADCP measures underwater currents. Dr David Maddison describes all three in detail, plus some related technologies.

USB SuperCodec

If you want to record and play back audio with extremely high fidelity, or measure the performance of a wide range of audio equipment including amplifiers then this project is for you. It's a 192kHz, 24-bit stereo USB sound card with impeccable performance and it can be combined with some low-cost software to measure distortion, signal-to-noise ratios, frequency responses and other audio device parameters.

Note: these features are planned or are in preparation and should appear within the next few issues of Silicon Chip.

The August 2020 issue is due on sale in newsagents by Thursday, July 30th. Expect postal delivery of subscription copies in Australia between July 28th and August 14th.

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Notes & Errata

H-Field Transanalyser, May 2020: the frequency counter module part number is miswritten as PJL-6LED on pages 40, 42 and 44. The correct part code is PLJ-6LED.

Nutube Guitar Overdrive & Distortion Pedal, March 2020: the Jaycar Cat PS0190 jack socket specified in the parts list is too tall to fit. Jaycar Cat PS0195 is a better fit, but some plastic must be filed off the jack for the adjacent relay to fit properly. Also, it's best to install the 100µF capacitor next to the socket after the socket itself.

Super-9 FM Radio, November & December 2019: the NXP BB156 Varicap diode used in this project is being discontinued. While it is currently still available, should it become difficult to source, the Toshiba 1SV304TPH3F is a suitable substitute.

Ultra Low Noise Remote Controlled Stereo Preamp, March & April 2019: on page 44 of the April 2019 issue, endstop adjustment trimpot VR4 is incorrectly referred to in several places in the text as VR2.

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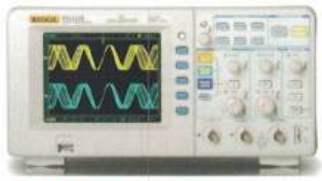

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